Proceedings

INDO-PACIFIC FISHERIES COUNCIL

PROCEEDINGS

3RD MEETING—1ST–16TH FEBRUARY 1951
MADRAS—INDIA

SECTIONS II AND III

MADRAS, 1952

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Section II

TECHNICAL PAPERS

1

A COMPARISON OF THE HYDROLOGICAL CONDITIONS OFF THE EASTERN AND WESTERN COASTS OF AUSTRALIA

by

D. J. Rochford*

ABSTRACT

A comparison is made of the hydrological properties of the two principal water types of the east and west Australian fringing waters and the general validity and application of such a method to comparative estimates of oceanic fertility and to the ecology of wide-ranging fish species, such as the tunas for example, are discussed.

In October 1950 deep sea oceanographical section lines were worked off the east Australian coast in latitude 34°S. by R.R.S. " Discovery II " and off the west Australian coast in latitude 32°S. by F.R.V. " Warreen ". The section on the east extended 200 miles offshore, and that on the west 100 miles.

As the east Australian section was worked (on October 8 and 9, 1950) only three days later than the west Australian, it was the original intention to use these oceanographical data or a synoptic comparison of the hydrological properties of the fringing Pacific and Indian Ocean waters in comparable latitudes. Subsequently, however, the study was broadened by the use of previous oceanographical data of the area and more general conclusions were reached.

Methods of Analysis.—The methods followed in the collection, laboratory analysis and computation of the data used in this paper are given in the introductory section of the respective station list of Australian oceanographical data issued by C.S.I.R.O., Fisheries Division (in press).

Material.—The raw data used in the preparation of this paper are given in station lists of recent Australian oceanographical data, to be published by C.S.I.R.O., Fisheries Division, Cronulla, and in station lists of the " Discovery " and " Dana " expeditions.

All the temperatures from the Australian station lists were corrected for mercury expansion errors according to the simplified formula of Tully (1937). The depth of reversal is a calculated depth, based upon thermometric measurements at fairly frequent depth intervals according to the theory of Schumacher (1923). Sigmat calculations have been made with Matthews' tables (1932).

IDENTIFICATION OF WATER TYPES

Helland-Hansen (1916) developed a classical method for the identification of primary water types in a water column by means of the variation in the curve expressing the relationship between salinity and temperature. Such a method can be followed only if the salinity and temperature of these primary water types can be treated as conservative properties and, as such, as being influenced only by relatively slow exchange with adjoining water masses.

The method has been used for the identification of primary water types in the fringing Pacific and Indian Ocean waters. Figs. 1 and 2 are examples

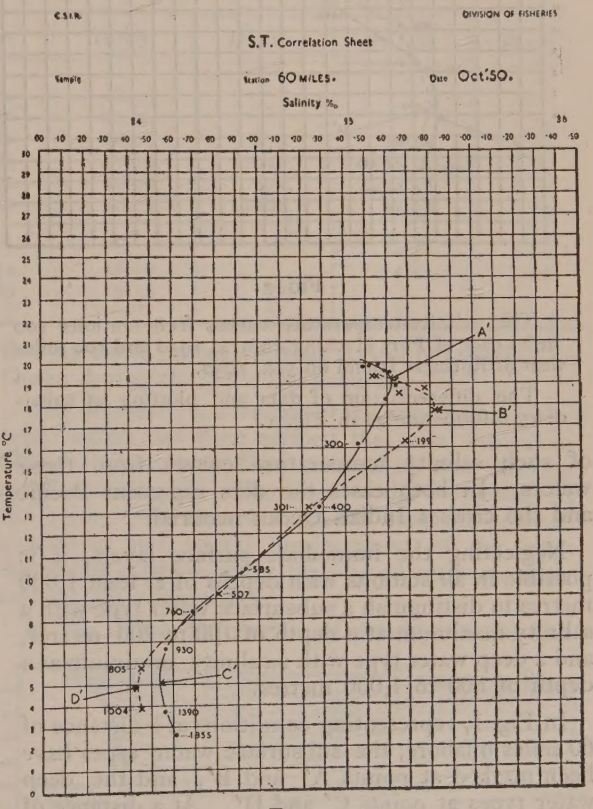

FIG. 1.

The salinity—temperature curves from stations 60 miles east of Port Hacking.————. on 9. x. 1950, and 60 miles west of Rottnest Islands ×————× on 5. x. 1950. The principal water types have been marked A', B', C' and D'. The actual sampling depths have also been plotted.

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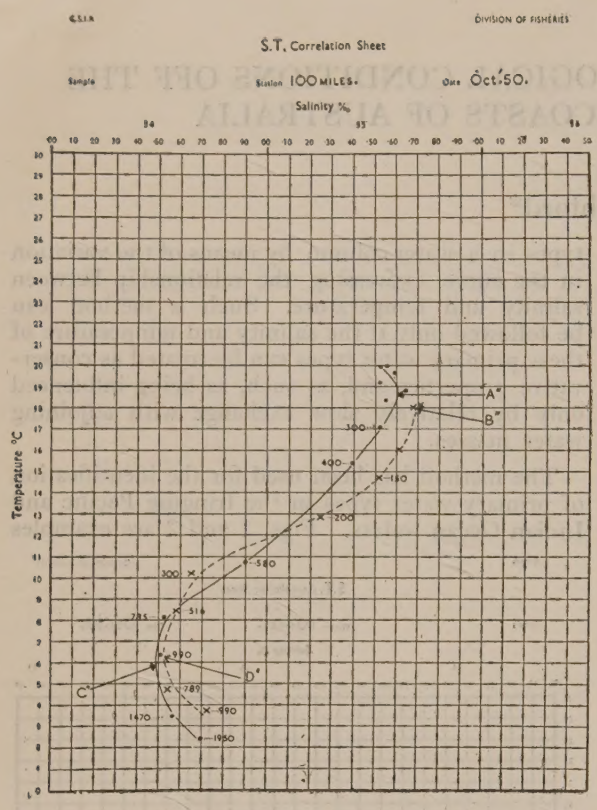

FIG. 2.

The salinity-temperature curves from stations 100 miles east of Port Hacking on 9. x. 1950 and 100 miles west of Rottnest Island on 5. x. 1950.

The differentiation of data and plotting of subsidiary information as in Fig. 1.

of such salinity temperature curves from these waters. In both cases the dots represent Pacific and the crosses Indian Ocean material.

Neglecting the immediate surface layers, it is possible in all stations with depths of at least 1,000 metres to distinguish a subsurface water type with a salinity maximum at a depth of 100 to 200 metres, and a deep water type with a salinity minimum at a depth of 800 to 1,000 metres.

In Fig. 1, representing conditions at a distance of 60 miles offshore, the subsurface water types have been marked at points A′ and B′, and the deep water types at points C′ and D′. At a distance of 100 miles offshore (Fig. 2), the equivalent water types can be distinguished at points A″, B″, C″ and D″ respectively.

At both stations in Fig. 1 it is possible to detect a surface water type whose properties would probably vary so much under the influence of local factors as to render its separate identification of doubtful value. In any case, the comparative shallowness of the subsurface water type facilitates mixing with, and enables it to act as a primary source for the genesis of these purely surface water types. In this paper, therefore, no attention has been paid to the immediate surface layers and the comparison of Indian and Pacific Ocean fringing waters has been based upon the properties of the subsurface and deep water types.

In Table 1 the depth, salinity and temperature of each of these water types at successive stations during the October surveys are given. Although some variation in the magnitude of these properties of the surface water types occurs between stations, the differences are such as one would expect local mixing exchanges to cause in an initially homoge-

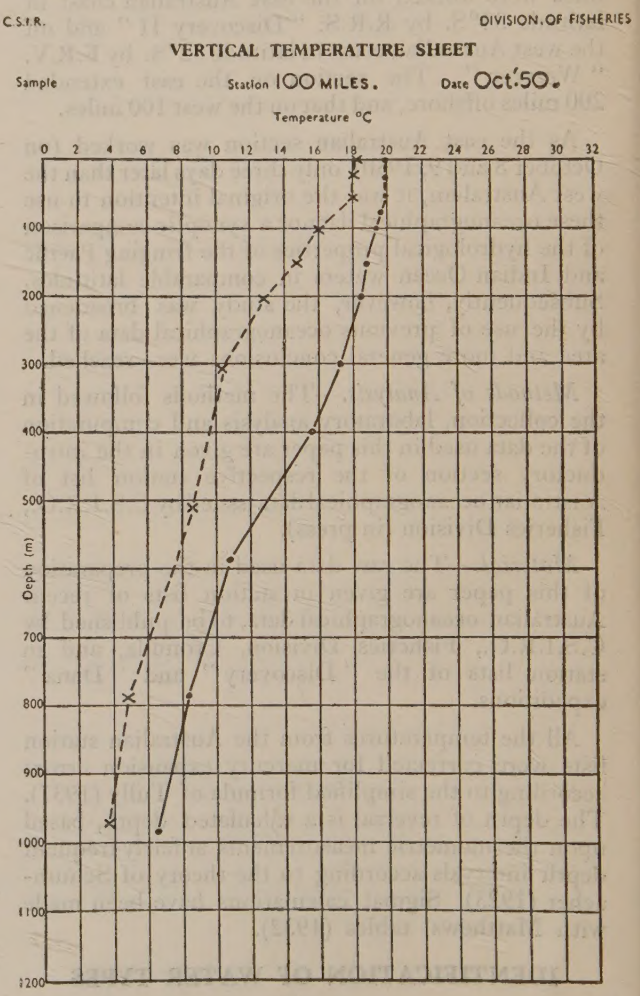

FIG. 3.

The vertical distribution of temperature at a station 100 miles east of Port Hacking In 9. x. 1950.————. and 100 miles west of Rottnest Island on 5. x. 1950 x————x.

neous water type, and are not sufficient to justify the rejection of the hypothesis of continuity of a single subsurface water type in the respective oceans. In the case of the deep water type, however, it is clear that we are not only dealing with the same water type in each ocean, but with a common inter-oceanic water type existing at this deep level. Its properties identify it as sub-Antarctic intermediate water and it has been designated accordingly.

The mean salinity of the subsurface water type is higher in the Indian than in the Pacific Ocean. The temperature of the latter water type is, however, higher. The vertical distribution of temperature at a distance of 100 miles offshore in the Indian Ocean, plotted as crosses, and the Pacific Ocean, plotted as dots, (Fig. 3) shows quite clearly the overall higher temperature of the latter ocean.

Although the properties of the sub-Antarctic water type are similar in both oceans, the depth of occurrence in the Indian is less than in the Pacific Ocean.

The bathymetric features of these two regions probably play a major role in such a difference.

TABLE I

The identifying properties of the subsurface and sub-Antarctic water types of the Indian and Pacific fringing waters during October, 1950

Ocean	Distance offshore	Water type					
		Subsurface			Sub-Antarctic		
		Depth	S°/oo	Temp.	Depth	S°/oo	Temp.
	miles	m.					
Indian ..	30	200	35.71	18.30			
Pacific ..	30	110	35.66	19.30			
Indian ..	60	125	35.82	18.00	870	34.44	5.00
Pacific ..	60	120	35.63	19.30	1020	34.54	5.00
Indian ..	100	0	35.70	18.00	670	34.52	6.40
Pacific ..	100	170	35.60	18.75	1020	34.48	6.00
Mean						34.48	5.70
Indian ..			35.74	18.10		34.51	5.50
Pacific ..			35.63	19.12			

In Fig. 4 the sectional distribution of density shows quite clearly the existence of a southward-flowing slope current in that region of the Indian Ocean during the period of sampling.

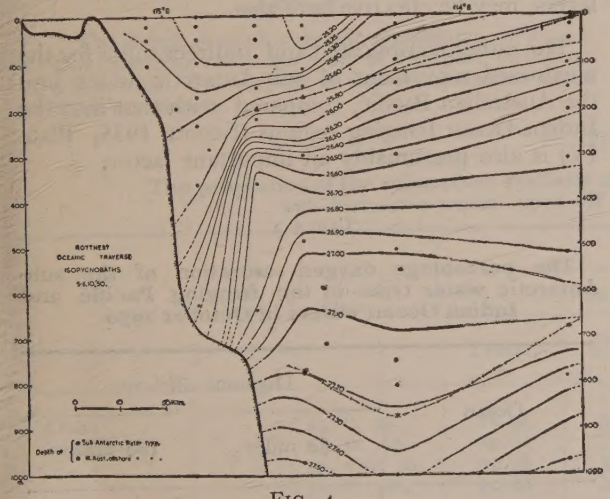

FIG. 4.

The distribution of density (σt) in a section extending 100 miles west of Rottnest Island on 5-6. x. 1950. The depths of the two principal water types are shown.

The depths of occurrence of the subsurface water type, which has been termed the west Australian offshore water, have been entered on this plotting as heavy triangles. The slope of the isopycnals in the upper 300 metres suggests that an onshore overlaying and lateral displacement of the west Australian offshore water type by an onshore slope current has occurred.

In Fig. 5 the distribution of density in the east

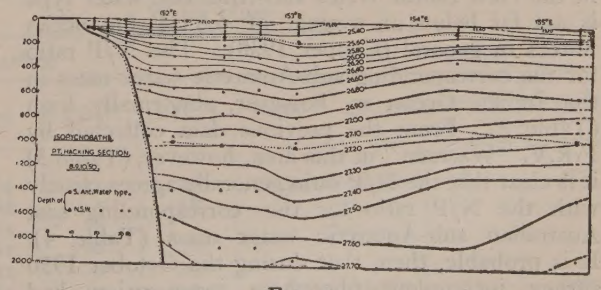

FIG. 5.

The distribution of density (σt) in a section extending 200 miles east of Port Hacking on 8-9. x. 1950. The depths of the two principal water types are shown.

Australian section is shown. There is no evidence in this section of any definite slope or offshore current in the surface zone of this area, which is rather abnormal for a region dominated by the well-developed east Australian current system and its local derivatives.

From the results of investigations by F.R.V. "Warreen" in this area (data in press) it is possible to deduce the occurrence of a large-scale eddy system as a normal feature of the late winter early spring period in this region. The disruption of the east Australian current system and the homogeneity of the surface layers in the section could be a normal consequence of the decay of this eddy system.

The depths of occurrence of the subsurface water type, which has been termed the New South Wales offshore water type, have been plotted on this section as solid triangles, and it can be clearly seen that no comparable dynamical displacement of it has occurred.

TABLE 2

The mean nutrient properties of the subsurface and sub-Antarctic water types in the fringing Pacific and Indian Ocean waters during October 1950

Ocean	Water type					
	Subsurface			Sub-Antarctic		
	Mean NO_3N $\mu g/L$	Mean PO_4P $\mu g/L$	N/P (by weight)	Mean NO_3N $\mu g/L$	Mean PO_4P $\mu g/L$	N/P (by weight)
Pacific ..	20	10	2	340	55	6.2
Indian ..	0	2	0	780	32	24.4

THE NUTRIENT PROPERTIES OF THESE WATER TYPES

In Table 2 is given the mean nutrient content of the subsurface and sub-Antarctic water types during October, 1950. The New South Wales offshore water type is much richer in both phosphates and nitrates than its Western Australian equivalent. The low N/P ratio in the New South Wales offshore water type is probably due to differences in the rates of local turnover of phosphates and nitrates, and of the differing depths at which full regeneration of phosphates and nitrates occurs.

On the other hand, in the sub-Antarctic water mass, in which one would expect to find relatively similar nutrient conditions, big differences are encountered. The nitrogen to phosphorus ratio in the New South Wales sub-Antarctic water type is not far below an average of 6.8 : 1 for ocean waters in general (Cooper 1938). The N/P ratio for the corresponding sub-Antarctic water mass in the Indian Ocean is, however, abnormally high (Table 2). From the previous data collected by F.R.V. "Warreen" in this area, however, (Table 5) it is clear that the N/P ratio generally agrees closely with the N/P ratio for the corresponding east Australian sub-Antarctic water mass (Table 4). It is probable, then, that during the October 1950 survey incomplete phosphate regeneration had occurred in this water type off the west Australian coast.

It is quite possible also that at any particular time the sub-Antarctic water types of the fringing Indian and Pacific Oceans have had their genesis during different periods of the nutrient calendar in the sub-Antarctic surface waters of south latitudes. A cyclical meridional variation in nutrient content, similar to that demonstrated by Deacon (1933) for dissolved oxygen in the South Atlantic deeper layers, may be effective here also.

The rather complicated and indirect route for the northward movement of sub-Antarctic water into the Australian Pacific, compared with that into the Indian Ocean fringing regions (Schott 1935, Plate IV) is also presumably an important factor.

TABLE 3

The percentage oxygen saturation of the sub-Antarctic water types in the fringing Pacific and Indian Ocean waters in October 1950

Ocean	Distance offshore	
	60 miles	100 miles
Pacific ..	53%	55%
Indian ..	64%	67%

The lower saturation figures for oxygen in the Pacific, compared with figures in the Indian Ocean sub-Antarctic water type (Table 3), can be considered as further evidence of the disparity in age of these water types, although it could be simply a measure of the degree of mixing exchange at this depth.

The difference in linearity of the S. T. curves at the 100 mile offshore station (Fig. 2) is evidence of less vertical mixing between the subsurface and sub-Antarctic water types in the Indian, compared with the Pacific Ocean, fringing waters. At the 60 mile offshore station (Fig. 1) more vertical mixing occurs in the Indian Ocean water column, and, at the 30 mile offshore station, there occurs an almost completely linear relationship of salinity to temperature in both oceans. Increasing interaction between the water column and the ocean bottom is probably the principal reason for this variation.

The cellular distribution of phosphates (Fig. 6) and nitrates (Fig. 7) at the slope and 100 mile station

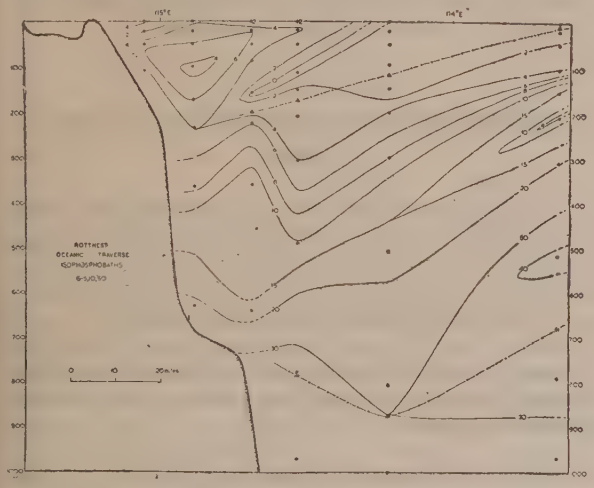

FIG. 6

The distribution of inorganic phosphates in a section extending 100 miles west of Rottnest Island on 5-6. x. 1950. The depths of the two principal water types are shown.

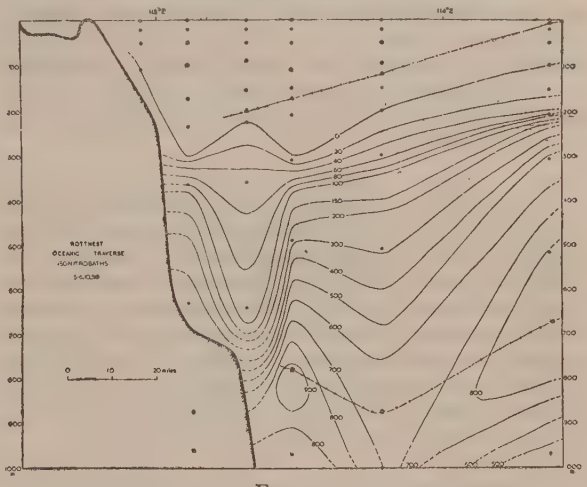

FIG. 7

The distribution of nitrate nitrogen in a section extending 100 miles west of Rottnest Island on 5–6. x. 1950. The depths of the two principal water types are shown.

on the Rottnest section, could be attributed in part to the imperfect vertical mixing in this region. However, the higher oxygen saturation of the sub-Antarctic water type (Table 3) in this region does not support such an hypothesis. The oceanographical work of F.R.V. "Warreen" in this area (data in press) has shown this cellular distribution of nutrients to be a normal feature of the west Australian fringing waters, and their occurrence must in all probability be attributed to *in situ* phenomena at the source of the component water types (see p. 64)

TABLE 4

The properties of the subsurface (salinity maximum) and of the deep (salinity minimum) sub-Antarctic water types off Port Hacking, New South Wales

Sample	Date	Water types							
		Subsurface				Sub-Antarctic			
		Temp.	S°/oo	PO_4P	NO_3N	Temp.	S°/oo	PO_4P	NO_3N
"Dana"	23. ii. 29.	19.94	35.64	11	25	5.54	34.50	64	450
"Warreen"	25. iv. 40.	19.01	35.62	5	48				
	12. viii. 40.	19.18	35.64	6					
	31. x. 40.	20.00	35.61	10	38				
	11. i. 41.	16.44	35.62	0	25				
"Discovery"	9. x. 50.	19.12	35.63	10	20	5.50	34.51	55	340
	Mean	18.95	35.63	7	26	5.52	34.51	60	395

THE SIGNIFICANCE OF THESE WATER TYPES IN THE HYDROLOGY OF THE REGION OF OCCURRENCE

In Table 4 are given the properties of the water at the subsurface maximum and at the subsurface minimum salinity layer. It is evident that the waters occurring at these levels are very comparable in hydrological properties with the New South Wales offshore and sub-Antarctic water types found in October 1950.

The continued existence of the New South Wales offshore water type over such a wide period and at most times of the year suggests rather conclusively that this water type is a persistent element of the east Australian system. Presumably it represents the water type or core of the east Australian current system, and its distribution in both the vertical and lateral planes is governed by the dynamics of this current system. Upon it as a foundation the local surface hydrological features are established.

Whilst there is no biological evidence as yet to support it, it is not unreasonable to suppose that a fishery such as the tuna fishery might be found associated with a subsurface water type of this nature. In this case, fluctuations in abundance of such a fishery would be dependent upon the volume of this particular water type and its depth distribution rather than upon immediate and local nutrient conditions, which in any case could not be of major importance to a wide-ranging fish of this nature.

In Table 5 the properties for all available data of the water at the depth of the salinity maximum and salinity minimum layer of the waters off Rottnest Island, Western Australia, are given. Although the mean salinity figure is almost identical with that encountered in October, 1950, the dispersion of the individual salinity figures is rather high and it is probable that we are not in this case dealing with a conservative water type of the east Australian pattern, but with a more variable water mass. The salinity of the sub-Antarctic water type at the depth of occurrence of the salinity minimum layer is also more variable than its east Australian equivalent.

It is also apparent that the very high nitrate figures for this water type in October, 1950 (Table 2) are rather abnormal and that the mean nutrient content is not very different from the mean for the same water type on the east Australian coast. A negative anomaly in the N/P ratio of the surface waters is a general feature of the west Australian subsurface water mass. The salinity minimum layer is also more variable than its east Australian equivalent. Undoubtedly, however, this deep water type is sub-Antarctic in origin.

The relationship of the subsurface west Australian water type or water mass to the comparatively ill-defined and irregular west Australian offshore current is not as consistent as the corresponding relationship on the east Australian coast. It is probable, however, that it represents the fundamental and most persistent subsurface water type of this region and that as is the case off the east Australian coast, its properties represent a base level upon which the effects of local factors are superimposed.

Considered in this light, therefore, the comparative nutrient poverty of the Indian compared with the Pacific Ocean subsurface water types (Tables 4 and 5) could be of considerable importance.

ORIGIN OF THE SUBSURFACE WATER TYPES

The salinity temperature properties of the New South Wales offshore water type are within the range of those of surface sub-tropical waters of low latitudes. However the nutrient content, and in particular the phosphate content, is rather high for such an origin and it seems likely, therefore, that it has originated in the deeper and nutrient-richer sub-tropical layers before its incorporation into the east Australian system.

From the general distribution of salinity and temperature in the Indian Ocean (Schott 1935) it is possible to postulate the origin of the west Australian offshore water type. In Plate XXVII Schott (*loc. cit.*) shows the existence of a central pool of water, with salinities of the same order as those of the west Australian offshore water type, lying between longitudes 80°E. and 110°E. Presumably then, the eastward drift from within this region (Schott *loc. cit.*, Plate XXX) carries some of this high salinity water into the west Australian region, where it constitutes the core of the west Australian current system.

Although no nutrient data are available for the central Indian Ocean, the origin of this water type from a region of probable isolation and nutrient impoverishment is also consistent with its low phosphate and nitrate content (Table 5). Schott (*loc. cit.*, Plate XXVI) also lists the central Indian Ocean region as having a negative surface temperature anomaly, which agrees with the temperature conditions prevailing off the east and west Australian coasts in comparable latitudes (Fig. 3).

TABLE 5

The hydrological properties of the waters at the salinity maximum and salinity minimum depths at the offshore stations off Rottnest Island, Western Australia, 1947-1950.

Source	Date	Water type							
		Subsurface				Sub-Antarctic			
		Temp.	S°/oo	PO_4P	NO_3N	Temp.	S°/oo	PO_4P	NO_3N
"Warreen"	9. xi. 47.	15.98	35.81	6	25				
		18.19	35.88	2	25				
	16. iv. 48.	19.40	35.82	8	0	4.49	34.43	42	455
	17. iv. 48.	19.25	35.88	3	0				
	24. viii. 48.	17.35	35.81	0	32				
		17.79	35.82	1	20	5.63	34.47	48	195
	11. xii. 48.					4.78	34.42	85	550
						4.16	34.51	75	455
	7. iv. 49.	20.15	35.98	7	0	6.09	34.60	27	180
						7.24	34.60	43	195
	7. vi. 49.	18.80	35.84	9	0				
	22. vii. 49.	18.42	35.90	2	0	4.32	34.58	50	481
	9. xi. 49.	17.24	35.75	3	0				
	24. ii. 50.	18.75	35.66	7	0	4.23	34.38	60	545
		18.56	35.66	8	0				
	22. iv. 50.	19.30	35.88	5	0				
	21. vi. 50.	19.53	35.95	2	0				
	5. x. 50.	18.10	35.74	2	0	5.70	34.48	32	780
	Mean	18.45	35.82	4.3	7.3	5.18	34.50	51.6	426

DISCUSSION AND CONCLUSIONS

In hydrology it is often difficult to make comparisons between the fertility and ecological characteristics of the immediate surface layers of different oceans. The changes in hydrological properties are often so rapid and localized in extent as to make any comparisons based upon a small number of sampling observations, statistically very unreliable.

The method that has been followed in this paper is therefore in the nature of an experiment to determine whether more stable, and hence statistically more reliable for a given number of observations, core layers can be isolated from each region and utilized for a comparison of their hydrological properties.

Moreover, from an ecological point of view it is more probable that these persistent rather stable core layers, rather than purely local variations in surface hydrological conditions, provide the clue to the ocean-wide distribution of such a far-ranging and fairly omnivorous fish group as the tunas. The origin and genesis of such water types may also provide valuable information upon the breeding phase and larval concentrations of such a fishery.

Bio-geographical indices of fish distribution are often based upon single variables of the environment, and in particular temperature. Whilst this conception has much general application, it is quite possible that in some fish groups a number of environmental factors acting in unison are responsible for geographical limits of their distribution and, in some cases, for the depth strata occupied.

The conception of water types or water masses as ecological niches with fairly narrow ranges of environmental variability, but with considerable variation in geographical and depth distribution and in interoceanic source regions, could provide an answer to some of the puzzling features of ocean-wide tuna distribution, and their habitats.

Whilst lack of sufficient breadth in the available oceanographical data rather limits the hydrological conclusions to be drawn from this paper, it is clear that certain basic and fairly persistent water types can be distinguished, and that the consistent differences in the nutrient content of the subsurface water types off the east and west Australian coast lines are significant in the basic fertility of these regions.

As to whether any persistent association of organisms, including fish groups, can be related to these water types cannot on available evidence be determined. As a working hypothesis, therefore, the concept of water types containing persistent association of organisms is suggested for investigation by the other members of the Indo-Pacific Fisheries Council.

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2

STATEMENT ON MARINE INVESTIGATIONS IN MALAYA

by

Tham Ah Kow*

Preliminary investigations were started in Malaya to elucidate the physical, chemical and biological characteristics of Singapore Straits and their inter-relationships. Meteorological data for the same period and locality were made available to the Malayan Fisheries Department by the Director of the Malayan Meteorological Service and these data were correlated with the physical, chemical and biological data in order to assess their respective roles in the marine ecosystem of Singapore Straits. At the same time a study of the food and feeding relationships of the more important members of the fish population was carried out. An attempt will be made to utilise the results of this investigation as a basis for predicting the availability of the more important elements of the fish population.

These investigations were started in January 1948 and continued till the end of December 1949. Samples of water were collected at fortnightly intervals throughout this period and the salinity and phosphate content determined by the usual standard methods. The temperature of the water was determined simultaneously and plankton samples were also collected by filtering sea water pumped from different levels between the surface and the sea bottom. The volume of the settled plankton was measured. The pigment content of an aliquot part of the sample was determined and expressed in Harvey units, whilst the numbers of phytoplankton and zooplankton organisms were also estimated.

At the same time detailed records were kept of the catch of three selected fish traps (Kelongs) in Singapore Straits. These fish traps are built by planting poles into the sea bottom to form two inter-communicating enclosures, the second of which is blind. Short rows of poles are also planted on both sides outside the entrance to the first enclosure. Fish moving with the tides are intercepted by a long lead which guides the fish into the first enclosure. The fish is removed from the second or blind enclosure by means of a lift net. A detailed description of this method of fishing has been given by LeMare and Tham. These traps are operated every day throughout the year in all conditions of tide and weather so that the fishing intensity is constant. The total catches of these traps around Singapore represent 70% of the total local landings so that they are considered to give a good indication of the availability of fish in Singapore Straits.

The data which have been obtained are being subjected to correlation analysis.

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3

AN INVESTIGATION OF THE RIVER GODAVARI AND THE EFFECT OF THE PAPER MILLS POLLUTION AT RAJAHMUNDRY

by

S. V. Ganapati and P. I. Chacko*

ABSTRACT

An investigation of the chemistry and biology of the River Godavari in relation to pollution by the effluents of the paper mills at Rajamundry is reported. A description is given of the pollution situation, and an account is given of the biota under natural and polluted conditions respectively. Suggestions have been made for the abatement of this pollution nuisance.

In all industrialised countries of America and Europe, it is not lawful to deposit in or allow to pass into water resources of the State any extraneous matter or any residuary solid or liquid from any refinery, tannery, distillery, chemical works, paper mills and other types of factories, which will be deleterious to fish or plant life. In India, which is fast progressing industrially, many manufacturing undertakings are started near dams, hydro-electric reservoirs and rivers where power and water are available. Factory refuse is allowed to accumulate close to such industrial concerns and to pollute the nearby water resources. As industries and population continue to grow, pollution of water resources by factory wastes becomes an ever-present problem requiring continuous and vigorous attention in view of the need for the conservation of all existing food supplies and the preservation of fish life and other material resources for the benefit of the present and future generations.

In India, Hora (1942) was perhaps the first to draw attention to this serious problem from the fisheries aspect ; and Hora and Nair (1944) made a scientific study of the effluents of the Quinine Factory at Mungapoo in Darjeeling, Bengal, from this point of view. Bhimachar and David (1946) studied the effects on the Bhadra river fisheries of factory effluents from the Mysore Paper Mills and the Mysore Iron Works at Bhadravati. Ganapati and Alikunhi (1950) studied the factory effluents from the Mettur Chemical and Industrial Corporation Ltd., Mettur Dam, Madras, and their pollutional effects on the fisheries of the river Cauvery. Factory effluents from the Andhra Paper Mills at Rajahmundry are polluting the river Godavari, causing mortality of fish during the non-flood season (January to June). Since remedial measures should be taken in the interests of preservation of game and food fishes of this river, an investigation of this problem was made from 1946 to 1950. The results of this study form the basis of this communication.

PHYSICO-CHEMICAL NATURE OF THE EFFLUENTS

The wastes discharged from the mills come from (a) the manufacture of pulp from different raw materials, such as bamboos, rags and waste paper, (b) purification of pulp, and (c) the manufacture of craft paper. Each of these processes is carried out in three different sections (Fig. 1).

In the preparation of fibre for the paper, 30% of the pulp used is from bamboos, 10% from rags and 60% from waste paper. The main process of making pulp from bamboo consists of removing the non-cellulose portion like lignin by treatment under pressure with a solution containing 80% caustic soda and 20% sodium sulphide. The waste ligneous liquor, after further treatments for chemical recovery, is very dark in colour and contains sulphides, sulphates, lime, soda and suspended matter. It is lead out separately by a channel and is accumulated in a tank outside the premises of the mills before discharge into the river.

Old gunny bags, rags, etc., are boiled with lime or soda and washed with water, while waste papers are sorted out and kneaded into a pulp with water and steam. These pulpy materials are made ink proof by the addition of rosin and alum. The effluent from the pulp section thus consists of excess water used for washing and screening the pulp. This waste water along with lime sludge of the causticizers goes in a drain, and passes through baffle walls where lime sludge is deposited and then passes out as effluent.

The effluent from the paper section consists of water and minute particles of pulp in suspension. This is taken by a separate drain to settling tanks from which it passes out as a yellowish oily supernatant liquor containing about 0.01% of resin and alum.

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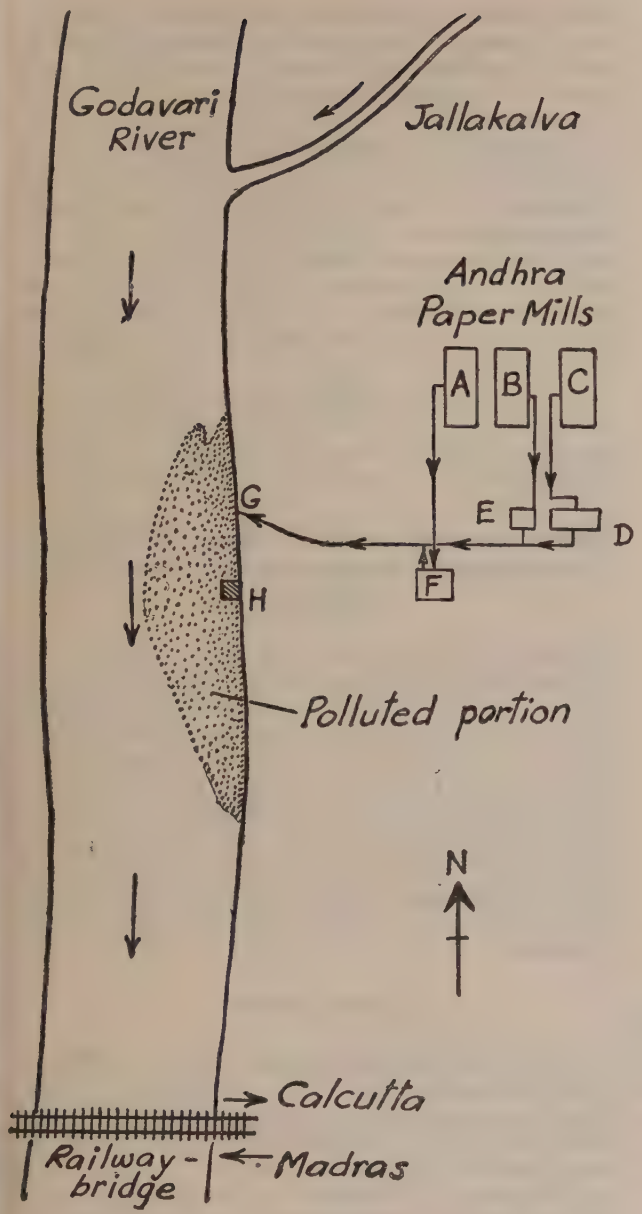

FIG. 1.

DIAGRAM SHOWING GODAVARI RIVER NEAR ANDHRA PAPER MILLS, RAJAHMUNDRY.

A: Raw Materials Section. B: Pulp Section. C: Paper Section. D: Settling Tank for C. E: Settling Tank for B. F: Storage Tank for A. G: Outfall of Common Effluent Channel. H: Intake Tower.

The effluents from these three sections then mix together and flow into the river through an open drain. The total quantity of effluents discharged from the mills in a day is about 60,000 gallons. The results of two typical analyses of the effluents from the three sections and from the final outflow channel are shown in Table I, from which it will be seen that the effluent from the raw materials section is noxious while those from the other two sections appear to be harmless. But the mixture which reaches the river is also harmful as is evident from the results of experiments given in Table II, from which it will be noted that the liquid has the capacity to reduce the oxygen content of stagnant water. Further, similar samples when stored for a week became darker, forming flocculent precipitates and also producing hydrogen sulphide. Similar action is likely to take place if this black liquor is allowed to stagnate in any open place.

CONDITIONS OF EXISTENCE IN THE RIVER GODAVARI

The Godavari river is in flood from July to December and during the rest of the year it contains little water with practically no flow. During flood the river is characterised by great velocity of flow, fluctuating depth and muddy discolouration. During this period it is not possible for the mills' effluents to reach the river by gravitational flow, because the flood water backs up through the outflow discharge channel. It is only when the level of water in the river falls below that of the canal that the effluent is freely discharged into the river. But at this time there is not much flow in the river and therefore proper mixing and dilution of the effluent seems not to take place.

The physico-chemical conditions of the river during the floods (Table III) show that the effluents have no effect on the river during this period. This river stretch has been found by Chacko (1946, 1949), Chacko and Ganapati (1950), and Job and Chacko (1947) to be the spawning and nursery grounds of major carps such as *Catla catla*, *Cirrhina mrigala*, *Labeo fimbriatus*, *L. calbasu*, *L. boga*, *L. ariza*, *Thynnichthys sandkhol* and *Puntius kolus*. Chacko (1947) and Chacko and Ganapati (1949) have observed the Indian Shad, *Hilsa ilisha*, performing its migration through this river stretch.

During the non-flood season (January to June) the river becomes lentic in condition. The level of water gradually goes down because of both evaporation as well as of the draw-off for irrigation purposes. It is during this period that the effluents from the mills cause harm to the fish population within a limit of about 1 mile below the outfall.

A bird's-eye view of the river from the embankment of the river where the effluents are discharged (Fig 1), as on 13th April 1950, presented an interesting sight. For about one mile below the outfall and one furlong above it and about four furlongs towards the middle of the river, the river water was

black in appearance. Beyond this region the water was bottle-green in colour. The black portion was the area affected by the effluents. This dry weather condition continues till the end of June and the area of pollution is thus bound to increase much further within that period.

In the polluted area, soft, fluffy, floating, decomposing, flocs of aluminium hydroxide and organic matter were seen in abundance. Copious gases were also seen escaping from the bottom on probing with a stick. The depth of water in these places was about 4 to 5 feet only. Samples of water taken from these places contain oxygen in fair amounts (5.026 cc/1) while near the outfall it was very low (0.838 cc/1). The other physico-chemical conditions are detailed in Table IV.

Trial nettings with a cast net revealed the presence of small species of fishes such as *Barbus ticto*, *B. stigma*, *Rasbora daniconius*, *Ambassis ranga* and *Glossogobius giuris*, and the prawn *Palaemon malcolmsonii*. Macrovegetation like Hydrilla, Vallisneria and Potamogeton were present only in the sheltered portion just above the outfall. The phytoplankton was represented by few individuals of Myxophyceae (Amphithrix, Merismopedia, Microcystis and Oscillatoria), Chlorophyceae (Cladophora, Cosmarium, Oedogonium, Pediastrum and Penium), Bacillarieae (Amphora, Cymbella, Gomphonema, Navicula, Nitzschia, Surirella, Synedra and Tabellaria) and of Euglenophyceae (Euglena and Phacus). The zoo plankton was represented by rotifers (Brachionus, Euchlanis, Noteus, Notholca, Pedalion, Rattulus and Rotifer) and copepods (Diaptomus and Eucyclops). The bottom fauna consisted of dipteran larvae (Chironomus), worms (Chaetogaster) and gastropods (*Vivipara variata* and *Paludomus stomatodon*). Dead shells of *Corbicula striatella*, *Melania tuberculatus*, *Indoplanorbis exustus* and *Limnaea succinea* were found scattered about at the bottom.

The physico-chemical conditions of the non-polluted portion of the river is given in Table IV, from which it will be seen that in this region the water is not only bottle green in colour, indicating the presence of phytoplankton, but is also highly alkaline (pH : 8.5) and highly oxygenated (85 to 93% saturated). The plankton was rich and varied and consisted of Myxophyceae (Amphithrix, Anabaena, Merismopedia, Oscillatoria and Tetrapedia), Cyanophyceae (Coelastrum, Closterium, Cosmarium, Dictoysphaerium, Euastrum, Genicularia, Golenkinia, Gonatozygon, Oocystis, Pandorina, Pediastrum, Penium, Pleurococcus and Sphaerocystis), Bacillarieae (Amphora, Cymbella, Eunotia, Gomphonema, Gyrosigma, Navicula, Surirella and Synedra), Dinophyceae (Glenodenium), Euglenophyceae (Euglena), Rotifera (Brachionus, Euchlanis and Notholca), Cladocera (Diaphanosoma, Alonella, Simocephalus, Daphnia and Bosmina), Ostracoda (Cypridopsis), Copepoda (Diaptomus and Eucyclops). The bottom fauna was also rich, and consisted of Pelecypoda (*Lamellidens marginalis* and *Corbicula, striatella*) and Gastropoda (*Melania tuberculatus*, *Indoplanorbis exustus*, *Vivipara variata* and *Paludomus stomatodon*). The catches of fishermen who were operating in the river at the time of investigation were examined and found to consist of a variety of species such as *Wallago attu*, *Pseudotropius taarkee*, *Mystus aor*, *M. seenghala*, *M. cavasius*, *Labeo fimbriatus*, *Cirrhina reba*, *C. mrigala*, *Catla catla*, *Thynnichthys sandkhol*, *Amblypharyngodonmola*, *Barbus sarana*, *B. stigma*, *Rasbora daniconius*, *Chela bacaila* and *Rohtee cotio*. Prawns such as *Palaemon malcolmsonii* and *P. scabriculus* were also present.

PHYSIOLOGICAL RESPONSES OF FISHES TO DIFFERENT CONCENTRATIONS OF THE EFFLUENT

Laboratory experiments were made to study the response of *Barbus stigma* to the effluents. It was found that this species died immediately when placed in the black effluent from the raw materials section, and survived for only 15 minutes in the effluent from the pulp section and for three hours in the effluent from the paper section. In the mixture of effluents discharged into the river it died within half hour. By further experiments it was ascertained that the fish survived for several hours in a dilution of one part of the effluent to 500 parts of freshwater.

DISCUSSION

There is no doubt that the effect of the effluent from the Andhra Paper Mills is harmful to both fish life and fish food organisms. The effluent is black and offensive, reduces oxygen content of water and generates hydrogen sulphide. There is also deposition of aluminium hydroxide flocs with organic matter covering the river section near the mills, owing to the presence of alum in the effluents. A marked difference is noticeable between the polluted and non-polluted section of the river, the latter being characterised by optimum hydrobiological conditions which are suitable for supporting a rich fish fauna. It has been experimentally determined that a minimum dilution of 1 : 500 is necessary for safely letting the effluent from the mill into the river. It has been suggested to the authorities of the mills that the effluents should either be pumped into the river only when the latter is in high floods or that they should be purified

by some sort of rough and rapid filtration through sand before being discharged into the river.

ACKNOWLEDGMENTS

We are indebted to Sri T. R. Krishnaswami, General Manager of the Andhra Paper Mills, Rajahmundry, for affording us necessary facilities during the present investigation, to Srimati L. Saraswathi Devi, Algologist, for determination of the phytoplanktonic organisms, and to the Director of Fisheries, Madras, for according necessary permission for the communication of this paper.

SUMMARY

The Andhra Paper Mills situated on the left bank of the Godavari river near Rajahmundry, discharge about 60,000 gallons of its effluents into the river per day during the non-flood season. These effluents are noxious, being black and offensive, reducing the oxygen saturation of the river water. Flocs of aluminium hydroxide form and cover the surface and bottom of the river in the vicinity. The hydrobiological conditions of the river during the flood and non-flood season in the polluted and non-polluted regions were studied. The oxygen content near the outfall of the effluents was as low as 0.838 cc/1. Fish life was represented by a few small species. The plankton and the bottom fauna were also poor. On the other hand, the conditions were satisfactory in the non-polluted area, which was rich in plankton, bottom fauna and fish life. Laboratory experiments showed that dilution to 1 : 500 is necessary to prevent the deleterious effect of the effluents. Suggestions for the disposal of the effluents have been made.

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TABLE I

Showing results of analyses of physico-chemical conditions of effluents from the Andhra Paper Mills, Rajahmundry

Description	Raw materials section		Pulp section		Paper section		Mixture of all effluents
	23-10-46	13-4-50	23-10-46	13-4-50	23-10-46	13-4-50	23-10-46
Colour ..	inky	pitch dark	brownish	yellowish	yellowish	dirty yellows	dark brown
Turbidity—cm. ..	0.0	0.0	6.5	10.4	19.5	10.0	10.0
Time ..	1.0 p.m.	9.25 a.m.	12.15 p.m.	9.5 a.m.	12 N	8.55 a.m.	12.20 p.m.
Temperature—°C ..	45.0	31.4	40.4	40.9	37.9	41.1	39.1
Free Co_2 pp, 100,000	H_2S	H_2S	nil	..	0.431	..	nil
CO_3 ,, ..	smelling	smelling	9.0	..	..	..	2.25
HCO_3 ,, ..	..	..	7.930	..	10.938	..	11.742
Chloride ,, ..	..	..	2.9	2.0	2.3	2.08	2.5
pH ..	6.0	6.0	9.4	6.4	7.3	6.5	8.5
Dissolved o_2—cc/1 ..	nil	nil	1.628	..	3.165	..	2.442

TABLE II

Showing oxygen consuming capacity of the effluent of the Andhra Paper Mills, Rajahmundry

Ratio of effluent to tap water	Dissolved oxygen in cc. per litre in 3 minutes at laboratory temperature.
(1) Tap water only (control)	2.059
(2) 1 cc. of effluent in 250 cc. of tap water	1.326
(3) 5 cc. ,, ,,	0.977
(4) 10 cc. ,, ,,	0.488
(5) 20 cc. ,, ,,	0.349
(6) 40 cc. ,, ,,	Nil

TABLE III

Showing physico-chemical conditions of river Godavari during the flood season

Description	Below railway bridge	Opposite effluent outfall	Opposite Jallakalva.
Date	17-7-1948	17-7-1948	17-7-1948
Time	8.30 A.M.	12.10 P.M.	5.30 P.M.
Colour	brownish	brownish	brownish
Turbidity—cm.	2.0	2.0	1.5
Temperature oC	29.1	30.1	29.1
Free CO_2, pp. 100,000	2.24	nil	nil
CO_3, ,, ...	nil	1.2	0.9
HCO_3, ,, ...	15.555	7.930	6.405
pH	7.3	7.8	8.3
Dissolved O_2, cc/1	3.065	4.126	4.876
%saturation	54.6	74.7	86.4
Chloride, pp. 100,000	1.4	1.2	1.0

TABLE IV

Showing physico-chemical conditions of the polluted and non-polluted stretches of river Godavari, as on 13th April 1950.

Description	Polluted area			Non-polluted area		
	Near outfall of effluent	One furlong below outfall	Near intake tower	Four furlongs in front of outfall	6 furlongs in front of outfall	One mile below outfall
Time	10.5 a.m.	10.20 a.m.	11.0 a.m.	10.30 a.m.	10.50 a.m.	11.10 a.m.
Colour ..	deep brown	deep brown	brown	dirty green	bottle green	greenish
Temperature—oC ..	39.1	32.4	30.9	30.6	30.4	30.6
Free CO_2, pp. 100,000	0.502	0.495	..	..	..	..
CO_3, ,, ..	nil	nil	0.590	0.886	0.886	0.886
HCO_3, ,, ..	19.505	20.707	16.806	17.106	16.505	16.505
pH ..	7.7	7.6	8.45	8.5	8.45	8.45
Dissolved O_2, cc/1 ..	0.838	1.326	4.886	4.706	5.165	5.026
% saturation ..	..	..	88.9	85.3	93.2	91.1
Chloride, pp. 100,000 ..	..	3.4	3.2	3.3	3.3	3.0
Phosphates ($_2Po_5$) ,, ..	..	trace	trace	trace	trace	trace
Silicate (Sio_2) ,, ..	..	1.1	1.3	1.2	1.3	1.3

4

A CONTRIBUTION TO THE BIOLOGY OF THE SILVER BELLY, LEIOGNATHUS SPLENDENS (CUV.)*

by

H. L. Arora**

ABSTRACT

A study of the biology of *Leiognathus splendens* in Indian waters is reported. Length at first maturity, spawning period and frequency, growth rate (in the first two years), fecundity and length/weight relation have been studied.

The silver belly, *Leiognathus splendens*, is a small fish attaining an average length of about ten centimeters. It belongs to the family Leiognathidae. The body of the fish is oblong and compressed and the mouth is protrusible. The colour is silvery and hence the name silver belly. The species is widely distributed in the Indo-Pacific region. Its occurrence is reported in the seas of India, Malaya, Indonesia, China, Philippines, Queensland and the Fiji Islands.

In India, *L. splendens* is the subject of an important fishery at Thangachimadam on the Rameswaram Island, the annual landings being 500 tons which bring a total value of nearly Rs. 200,000 (Rs. 4.72 = ca. $1 US in 1951) to the fishermen. There is no fishing for silver bellies during the months from December to February.

The fish is captured by means of a bag net (local name—*Mada valai*) which is of conical shape and of small mesh of ½ inch. The net varies in length from 36 to 40 feet with a mouth opening of about the same diameter. The net is operated from two boat catamarans and at a depth of 3 to 6 fathoms.

Although there are two species of the silver bellies, *Leiognathus splendens* and *Leiognathus ruconius*, landed at Thangachimadam, the former constitutes by far the larger element in the commercial catch. This study deals exclusively with the biology of *L. splendens*.

The work was started in September, 1949, and the data presented in this paper have been gathered entirely from the commercial catches at Thangachimadam. Because the fishery does not operate in December, January and February, no data were available for these months. The gap still remains to be filled, yet a certain pattern of life history is evident and some general conclusions are drawn which will be useful in directing the future development of the fishery and measures for its conservation.

The measurements which have been used throughout this paper are the standard length of the fish, that is, from the tip of the mandible of the closed mouth to the origin of the caudal fin, recorded in millimeters.

The author wishes to express his sincere thanks to Dr. N. K. Panikkar, Chief Research Officer, Central Marine Fisheries Research Station, Mandapam, for his valuable suggestions in the preparation of this report.

SPAWNING PERIOD

The length of the spawning period was determined by a gross examination of the gonads of all

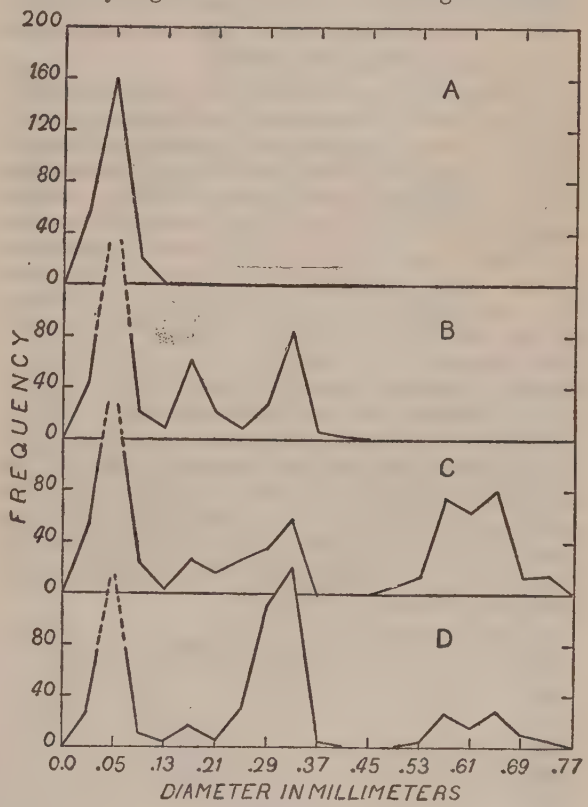

FIG. 1.

Frequency distributions of the egg diameters. A. Immature females. B. Intermediate females. C. and D. Mature females.

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** From the Central Marine Fisheries Research Station of the Government of India, Mandapam Camp.

fish studied, and by detailed measurements of the diameters of the eggs from a large number of females. Three stages in the development of the eggs were recognized. Stage I consisted of immature eggs only, ranging in diameter to about 0.135 mm; stage II, an intermediate group of eggs ranging from 0.135 to 0.375 mm; and finally stage III, mature eggs ranging in diameter from 0.445 to 0.775 mm. Frequency distributions of the egg-diameters from (1) immature females containing immature eggs only, (2) maturing females containing immature and intermediate eggs, and (3) mature females containing immature, intermediate and mature eggs, are shown in Figure 1.

The immature eggs are present in the ovary at all times of the year, but the intermediate and maturing groups are found only during the spawning season. It takes nearly two weeks for the intermediate eggs to differentiate into mature eggs. When the eggs are fully mature, they burst from their follicles and become segregated in the lumen of the ovary. The mature eggs are translucent and contain a single oil globule.

The females were classified by gross examination based on 'ova' characteristics into immature, intermediate or maturing groups. Immature ovaries contained no eggs visible to the naked eye; intermediate ovaries contained small, creamy-white, opaque eggs visible to the naked eye; maturing ovaries contained larger eggs which were translucent rather than opaque. Since the intermediate and maturing groups of eggs were never found in the gonads except during the spawning season, the presence of either one or both of these classes indicated that the fish would spawn within the next few days. Consequently, to determine the dates of the spawning season, fish of the intermediate class were grouped with those of the maturing class and only two categories used, immature and maturing. The percentage of adult females in the maturing group was calculated for each month for which data were available. The results are shown in Figure 2.

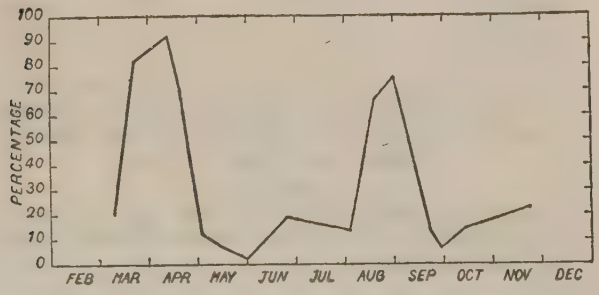

FIG. 2.

Percentage of maturing females recorded by months.

The curve in Figure 2 shows that a great majority of the adult females mature during the months of March and April and in August, and relatively fewer fish mature during the months of May, June and July. Obviously, the fish spawns from March till August or September but the peaks of spawning occur during the months of April and August. The males during these months were also seen fully mature.

FREQUENCY OF SPAWNING

It was found that by the time a group of eggs had attained maturity, a second maturing group was distinguishable at the upper range of the intermediate group. Such a group of maturing eggs appears between 0.25 and 0.37 mm in the lower graphs (C & D) of Figure 1. The second maturing group gradually develops from the intermediate class as the first maturing eggs increase in size, and by the time the first eggs are ready to be spawned the second lot can be clearly distinguished. Besides, in several instances, females with a maturing group of eggs in the ovary had also a few mature eggs lying in the lumen of the gonad. These eggs were undoubtedly the remnants of a previous spawning.

If there was only one spawning during a season, one would expect to find only two groups of eggs in the spawning female, i.e., the immature (Stage I) and the mature (Stage III). This was not the case in the fish examined and it is, therefore, reasonable to conclude that *L. splendens* spawns more than once in a season.

FECUNDITY

A series of 12 maturing gonads was examined by first weighing the gonads, then weighing small portions of the gonad and counting the eggs contained in each lot. Two portions were taken from each ovary, at anterior and posterior points, and an estimate was made of mean egg-weight of each ovary from these four samples. Direct computations of egg number from the gonad weights and the mean egg weight gave the following values:

Average length of fish		Number of eggs
58·6 mm	..	4,640
64·2 mm	..	6,445
70·0 mm	..	8,591
74·0 mm	..	10,588
Average	..	7,566

It is concluded from the above figures that *L. splendens* contains an average of 7,566 eggs. The larger fish may contain up to 11,000 eggs.

AGE AND GROWTH

The length-frequency method was used for the determination of age and growth in *L. splendens*. The length frequencies for the period for which data were available in the years 1949 and 1950 are shown in Table 1 and graphically in Figure 3.

TABLE I

Length-Frequency Distribution of *L. splendens* collected from Thangachimadam

Class range (mm)	Mid-point	1949			1950								
		Sep.	Oct.	Nov.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.
8-12	10	..	..	..	..	9	3	..	..	..	..	..	..
13-17	15	3	..	..	..	70	71	8	..	14	..	..	..
18-22	20	100	26	..	..	61	78	77	10	56	8	3	..
23-27	25	154	106	37	..	48	65	59	33	43	22	34	3
28-32	30	186	121	95	..	22	39	60	55	4	37	35	26
33-37	35	56	169	120	..	10	20	69	62	6	4	22	33
38-42	40	7	96	109	..	1	10	59	50	14	10	12	13
43-47	45	9	26	23	5	..	5	24	35	16	23	60	4
48-52	50	21	17	11	14	2	..	20	8	21	37	107	11
53-57	55	9	20	21	62	9	3	3	..	12	22	52	18
58-62	60	5	3	6	94	62	54	3	8	7	15	4	5
63-67	65	47	30	15	135	97	76	6	42	30	55	8	14
68-72	70	66	133	20	103	116	100	37	92	131	97	24	58
73-77	75	7	137	22	34	24	41	29	32	60	30	44	46
78-82	80	1	30	3	2	4	2	14	2	3	2	15	8
83-87	85	..	1	..	1	..	..	..	1	..	..	..	..
88-92	90	..	..	..	..	..	..	..	..	..	..	..	..
Total	..	671	915	482	450	535	567	468	430	417	362	420	239

The length-frequency histogram of the September 1949 collection shows three modes; the first at 30 mm, the second at 50 mm, and the third at 70 mm. The first two modes represent fish belonging to age-group I and the third mode represents fish belonging to age-group II. The fish of age-group I appearing at 30 mm must have been born in August and those of age-group I appearing at 50 mm, in April of 1949. The fish belonging to age-group II must have been born in April/August of 1948. The fish of age-group I born in April 1949 attain a length of 55 mm by November and enter age-group II in March of the next year at a modal length of 65 mm; those of age-group I born in August 1949 attain a length of 35 mm by November but are not discernible as a separate group in the length-frequency histograms of the next year. Presumably, they are included in the newly formed age-group II of the April 1950 collection. The fish of age-group II which attain a length of 72 mm in November 1949, do not appear to enter age-group III in the next year as there is no indication of mode in the 1950 collections which represent this age-group. It is probable that the fish do not live for more than three years and that they die sometime in the third year of their life but a possibility remains that they migrate into deeper waters. In the samples obtained from Thangachimadam no fish was found to attain a standard length of more than 85 mm.

The presence of two modes in the first year class was also observed in samples collected in August, September, October and November, 1950. This bimodality of the first year class is probably due to the fish spawning at its peak twice a year. It cannot be accounted for as being due to errors in sampling because the large numbers of fish constituting the samples obviate this possibility.

The rate of growth was estimated from the average modal length of the fish in each year-group in the collections taken from September 1949 to November 1950. These averages are plotted in Figure 4, and the growth curves are smoothed by eye. The year-classes are indicated by the date of spawning. Thus, the 1949 class constituted the age-group I until March 1950, when it was considered the age-group II. Fish which hatched in March 1950 attained an average modal length of 17 mm in April, 22 mm in May, 32 mm in June, 35 mm in July, 47 mm in August and 65 mm in November of the same year. Fish which hatched in March of 1949 attained a length of 65 mm by

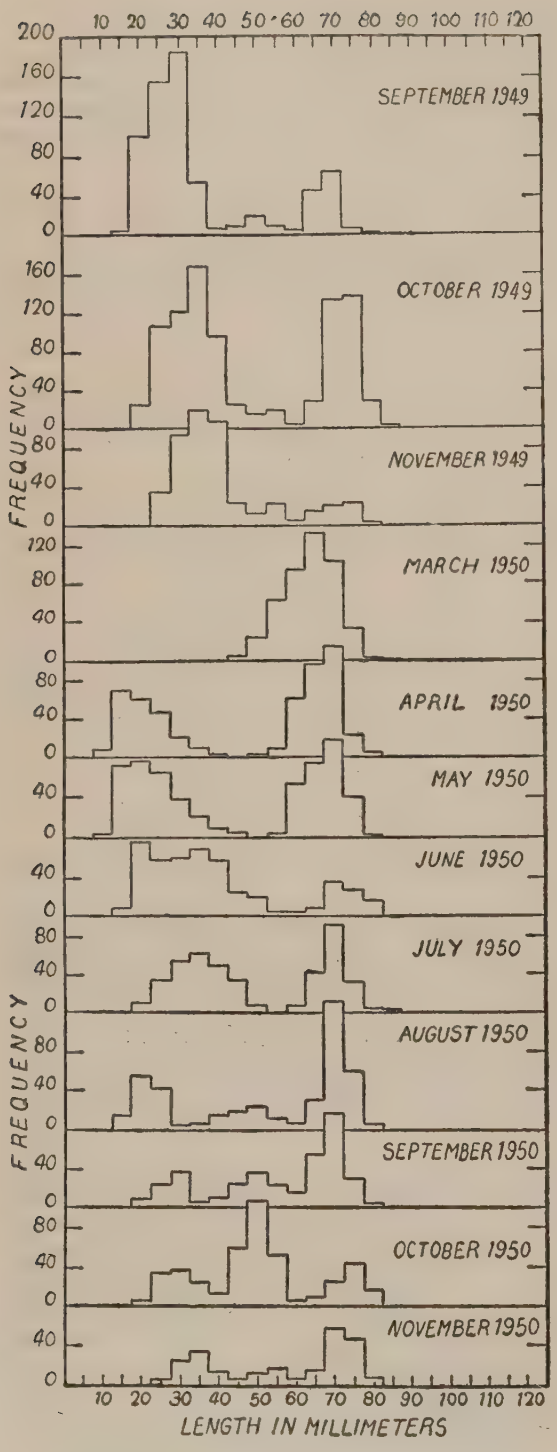

FIG. 3.

Length-frequency histograms of *L. splendens* collected from Tanganchimidam.

March of the next year when they entered the age-group II, and attained a length of 72 mm by November of 1950. It is evident that the growth in the first year is very rapid, the fish attaining a length of 65 mm at the end of the first year of its life. But

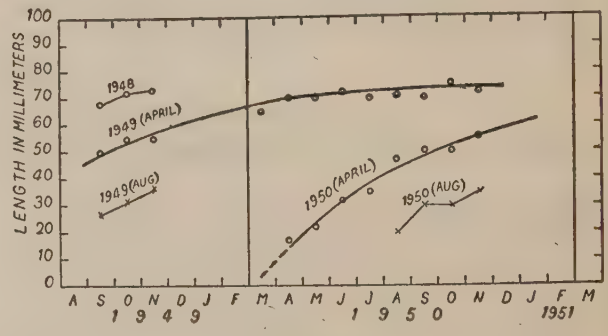

FIG. 4.

Average length of the year-classes at different seasons of the year, showing the growth rate during the first two years.

the growth in the second year is very slow, the fish attaining a length of only 72 mm at the end of the second year of its life.

SIZE AT FIRST MATURITY

In determining the size at first maturity, only fish taken during the peak of the spawning season were used. The presence of eggs of stage II (Intermediate) and of stage III (Mature) in the ovary was considered sufficient evidence that spawning would be accomplished during the same season. The number of immature and mature fish grouped by 5 mm length-classes are shown in Table 2. The percentage of mature fish among those of each length are plotted in Figure 5. The curve is smoothed with eye to show the trend.

TABLE 2

Number and Percentage of Mature Fish in Each 5 Millimeters of Length

Length in Millimeters	Total Fish Observed	Number Mature	Per cent Mature
38-42	12	0	0.0
43-47	25	0	0.0
48-52	43	0	0.0
53-57	58	4	6.8
58-62	44	23	52.0
63-67	52	51	98.0
68-72	36	36	100.0
73-77	11	11	100.0
78-82	5	5	100.0
83-87	1	1	100.0

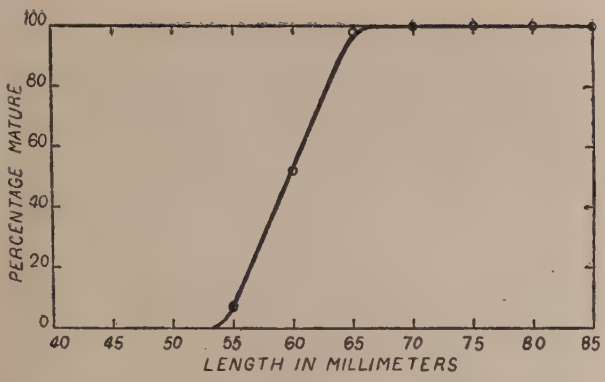

FIG. 5.

Percentage of females mature in each 5 millimeters of length.

The curve indicates that no mature fish was found with a length less than 50 millimeters. 6.8 per cent of the females were mature at 55 mm ; 52 per cent at 60 mm ; 98 per cent at 65 mm ; and practically all fish over 68 mm in length were mature. Thus it may safely be stated that *L. splendens* first matures at an average length of 60 mm or at the end of the first year of its life.

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship in *L. splendens* was determined through the use of the general formula

$$W = c\,(L)^n$$

$$\text{or, } \log W = \log c + n \log L$$

The formula is represented by a straight line when the logarithms are plotted. In the formula, W = weight, L = length, c = a constant which differs for different species, and n expresses the slope of the graph of logarithms.

The material of *L. splendens* was grouped into size classes of 5 mm and the logarithms of the means of the various groups were plotted. The resulting line was very definitely a straight line. The value of n was found to be 3.2 and that of log c,—4.8233. The equation relating log W to log L, therefore, was as follows :

$$\log W = -4.8233 + 3.2\ (\log L)$$

Or, expressed in the anti-log form :

$$W = .000015\ (L)^{3.2}$$

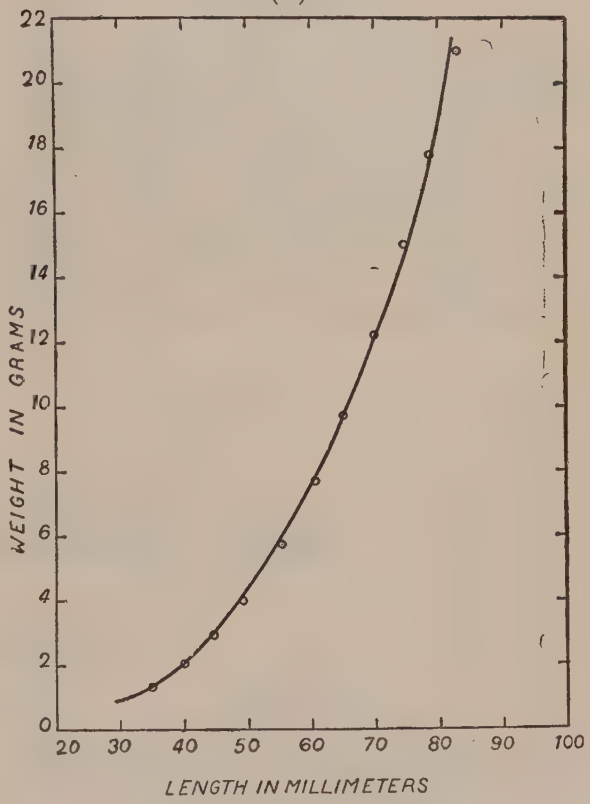

FIG. 6.

Calculated length-weight curve (solid line) fitted to the average length-weight values (dots).

TABLE 3

Average observed and calculated weights of *L. splendens* captured on May 30, 1950.

Size group (mm.)	Number of individuals				Average length (mm)	Average weight (gm)	Calculated weight (gm)
	Un-sexed	Male	Female	Total			
33-37	20	..	..	20	35.20	1.29	1.349
38-42	21	..	..	21	40.19	1.98	2.069
43-47	27	..	..	27	44.78	2.82	2.922
48-52	12	2	3	17	49.35	4.20	3.990
53-57	..	7	9	16	55.31	6.21	5.771
58-62	..	16	18	34	60.50	8.12	7.694
63-67	..	23	17	40	65.20	10.26	9.743
68-72	..	30	23	53	70.04	12.38	12.250
73-77	..	8	16	24	74.71	15.00	15.040
78-82	..	4	7	11	78.73	17.68	17.840
83-87	..	..	1	1	83.00	19.50	21.150

The calculated weights for *L. splendens* are shown in Table 3 and these give, as shown in Figure 6, a good fit to the class means of the observed weights. It is seen that the weight of *L. splendens* increases at a rate slightly greater than the cube of the length.

SUMMARY

The silver belly, *Leiognathus splendens*, forms an important fishery of Thangachimadam on the Rameswaram Island, the annual catch being 500 tons, bringing a value of nearly Rs. 2,00,000 to the fishermen. The principal gear used commercially for the capture of the silver belly is a bag-net (locally known as *Mada valai*) having a mesh of ½ inch. The net is operated from the boat catamarans. The fishing is done in depths from 3 to 6 fathoms.

L. splendens matures at an average standard length of 60 millimeters and spawns from March till September, the peaks of the spawning period being in April and August. The mature eggs are spherical, translucent, contain a single oil globule and measure from 0.51 to 0.77 mm in diameter. Each fish matures rapidly and spawns more than once in a season. An ovary contains an average of 7,566 eggs. The larger fish may contain up to 11,000 eggs. The length-frequency distributions for the months for which data were available show that *L. splendens* attains an average standard length of 60 mm at the end of the first year and 72 mm at the end of the second year of its life. No fish was observed to attain a standard length of more than 85 mm. The weight of the fish increases at a rate slightly greater than the cube of the length. The correct formula for the length-weight relationship was found to be $W = .000015 (L)^{3.2}$, where W = weight in grams, and L = length in millimeters.

5

THE LIFE HISTORY AND BIONOMICS OF AN INDIAN PENAEID PRAWN *METAPENAEUS DOBSONI*, MIERS

by

M. Krishna Menon*

ABSTRACT

This paper embodies the results of an investigation on the life history and bionomics of *Metapenaeus dobsoni*, one of the most important of the commercial species of penaeid prawns of the south-west coast of India.

MATERIAL AND METHODS

The life history was traced mainly by securing eggs and larvae from plankton collected at the surface and near the bottom from places ranging in depth from 2 to 13 fathoms, with nets made of organdy and ordinary mull. In addition to inshore hauls, offshore samples collected once a week from December 1949 to the end of May 1950 at places approximately 20 fathoms deep have also been examined. Nauplii and Protozoeae were obtained by hatching eggs and rearing the early larvae in small glass vessels and were compared with corresponding stages isolated from plankton. Late larval stages were secured both from plankton and by getting the immediately preceding stage to moult in the laboratory. Numerous individuals of the earliest post-larva obtained from plankton as well as from the last zoea (Mysis) were reared for varying lengths of time in order to establish specific identity and growth rate.

Adult and adolescent prawns have been collected from numerous brackish water localities such as Ennur and Pulicat near Madras, the mouth of the Adyar river in the same place, the backwaters along the Kerala coast and the mouths of some streams in the neighbourhood of Calicut. Samples from commercial catches were studied frequently. Valuable material was also available from the regular bi-weekly catches of fish made for the laboratory from the foreshore waters at West Hill, Calicut, up to a depth of 4 fathoms. Three types of nets are being used for this purpose, namely the gill net, the cast net and the boat seine locally called ' paithuvala ' and these collections proved invaluable, especially in the study of the bionomics of the species.

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* Prawns Research Officer, Central Marine Fisheries Research Station, Calicut. The writer wishes to express his thanks to Dr. N. K. Panikkar for his helpful suggestions in the preparation of this paper.

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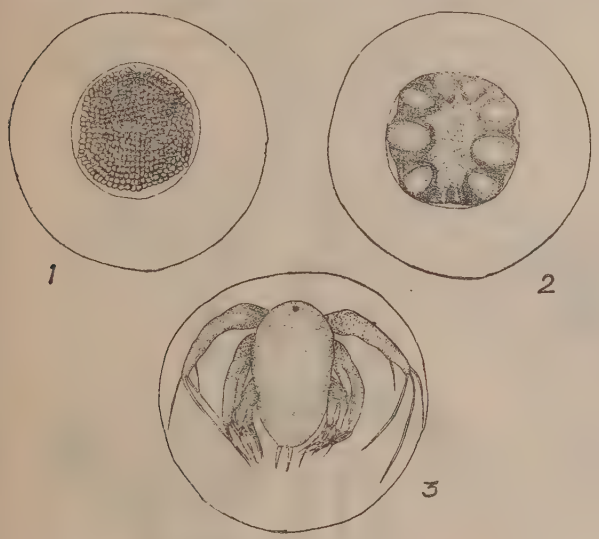
LIFE HISTORY

The life histories of a number of penaeids are fully known from the work of Gurney, Hudinaga, Dakin, Pearson and Mme Heldt. But none of the species are from Indian seas. The only published account of the larvae of an Indian form is that of *Penaeus indicus* given by the present writer (1937). Only the Protozoea and Zoea stages have been described, since the series was incomplete in the collection. So far as the genus *Metapenaeus* is concerned larvae of only one species are known, namely those of *M. stebbingi* described by Gurney (1927) from the Suez Canal. It will be evident from the following account that the course of development of the Indian species follows on closely parallel lines, having the same number of stages with numerous characters in common.



FIGS. 1–3. Ova of *Metapenaeus dobsoni*:
1. segmentation completed;
2. embryo with appendage buds;
3. fully developed nauplius.

Eggs. Figs 1-3. Eggs were obtained only from plankton, for there were no facilities for keeping mature females alive until they shed their eggs. Though penaeid eggs are believed to be demersal, large numbers of them belonging to *M. dobsoni* were found in plankton collections on several days made near the bottom as well as at the surface. They are buoyant and are easily stirred up by disturbances caused by currents or waves. These eggs have large perivitelline spaces like those of *Trachypenaeus constrictus* (Pearson 1939) rendering them much lighter than those of some other species and this peculiarity may account for their presence in surface samples.

With few exceptions the eggs obtained were in later stages of development. Two of them have been figured. One seems to be immediately after completion of segmentation, and the other with the rudiments of the 3 pairs of naupliar appendages developed as buds bent over the ventral surface of the embryo. Each egg measures 0.44mm in diameter and is perfectly spherical. In a few samples there were some slightly smaller, being only 0.35 mm in diameter. On hatching, the latter naturally gave rise to nauplii which were smaller, though the difference is too little to attract notice in a collection of both. Detailed study of the appendages failed to bring out any marked difference between the two sets of larvae either in this or the two subsequent stages. It seems fairly certain therefore that both sets of eggs belong to the same species. The eggs of *M. stebbingi* also are reported by Gurney to vary from 0.32–0.41 mm in diameter.

Both the early embryos and the fully developed nauplii do not fill the eggs completely, a wide space, the perivitelline space, being left around them. The embryo is closely invested by a thin embryonic membrane which ruptures later and the nauplius comes to lie within the egg membrane with the appendages partly straightened out so as to occupy the entire space inside. Eggs transferred to clean sea water in finger bowls or other glass containers kept cool by being stood in water, hatched invariably in the course of a few hours, the time varying, of course, with the state of development of the contained embryos. Some of the earliest batches of eggs secured in plankton behaved, however, in an entirely different manner. On 2 or 3 days in the month of September 1949, when the inshore water was extremely turbid due to rains and stormy weather, it was noticed that while some of the eggs kept overnight hatched normally, many did not hatch at all. In the latter set, however, the embryos continued to develop and in the course of the day had changed into protozoeae that were alive and showing movements though still enclosed within the embryonic membranes. They continued to live for a few hours, but later died, having failed to break the egg membranes. Though eggs were plentiful, larvae were surprisingly few in plankton on those days, showing thereby that either the vast majority of eggs perished without hatching or that the nauplii into which they hatched died soon afterwards.

As in *M. stebbingi*, there are only 3 naupliar stages, though in species of *Penaeus*, *Trachypenaeus* and *Sicyonia* several more stages have been observed by Hudinaga (1935), Mme Heldt (1938) and Pearson (1939). Nauplii hatched out early in the morning

were found to have passed into the first protozoea stage by next morning or a few hours later so that this phase in the life history apparently lasts only from 24 to 36 hours.

Stage I.—Figs. 4-5. Length from anterior to posterior end excluding caudal setae 0.26-0.28 mm.

It agrees closely with that of *M. stebbingi*. The body is opaque, pear-shaped and unsegmented and has a pair of short setae at the posterior end. A prominent hump-like elevation is present on the dorsal surface. Ventrally there is the labrum, which in this stage is in the form of an approximately conical process with no free flap extending backwards. A median nauplius eye is visible in front of several individuals. The usual 3 pairs of appendages namely antennules, antennae and mandibles are present, the two latter being biramous.

Antennules—Uniramous, unjointed with 5 setae at the extremity, 2 of which are longer than the rest.

Antennae—Biramous ; both rami unjointed. Exopodite with 5 setae along inner margin and tip ; endopodite with 3-4.

Mandibles—Biramous ; branches short, each with 3 terminal setae. No masticatory process.

The larva does not feed, nutriment being provided by the yolk material inside the body making it opaque. As it grows this is gradually used up with the result that the last stage is somewhat semi-transparent.

Stage II.—Figs 6-9. Length 0.33 mm

On the dorsal side a shell fold is plainly visible, its posterior margin being almost on a level with the base of the first pair of maxillae. Nauplius eye present in all. Posterior end of body, which carried anal setae in the previous stage, has elongated to become a short broad bilobed telson, each lobe carrying 6 setae, 2 on the outer margin and 1 inside being little more than points. Labrum is now free.

Antennules—Faintly segmented.

Antennae—Endopod with 4 terminal and 2 inner setae ; exopod with 4 faintly marked joints distally and 7 setae on inner margin and tip.

Mandible—A prominent hemispherical masticatory process at the base ; the 2 rami unchanged.

Rudiments of the 2 pairs of maxillae and first 2 pairs of maxillipeds have developed and are visible through the transparent cuticle.

FIGS. 4-5. Nauplius stage I :
(4) ventral view ; (5) side view.
FIGS. 6-9. Nauplius stage II :
(6) ventral view ; (7) side view ; (8) antenna ; (9) mandible.

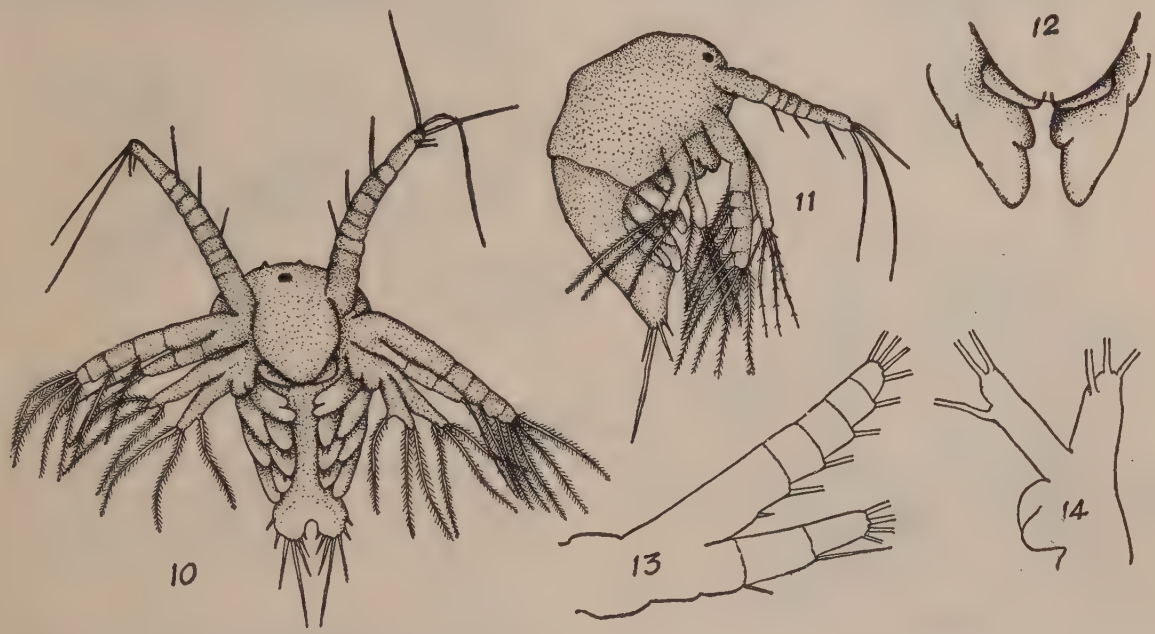
Stage III.—Figs. 10-14. Length 0.36-0.39 mm

This is the last nauplius. The body appears more slender than in the last stage. The shell fold extends backwards to include the somite of second maxilla and the telson has elongated further so as to form a conspicuous part of the posterior region of the body, the median notch of which has deepened. Its spine formula remains the same, but in older forms a minute point-like additional spine may be seen on the inner margin of each lobe. A pair of minute frontal organs are visible at the anterior end.

Antennule—Distinctly jointed with a few setae on the inner margin as in previous stage.

mass without pigment which later on becomes the stalked eye. In older larvae belonging to the same stage a patch of pigment develops at their outer extremities, The frontal organs are quite prominent and are slender and pointed. Such pointed frontal organs, as remarked by Gurney (1943), are present only in one other genus of Penaeinae, viz. *Parapenaeus*. All thoracic segments are well differentiated and the first abdominal somite is also faintly marked out.

Colouration.—A pair of branching reddish brown chromatophores at the posterior margin of the telson and one at the base of each second maxilliped; otherwise the larva is more or less transparent.



FIGS. 10-14. Nauplius stage III:
(10) ventral view; (11) side view; (12) labrum, paragnatha and maxilla 1; (13) antenna; (14) mandible.

Antennae—Exopod with 8 setae and a spinelike rudiment proximally; endopod two-jointed, but with the same number of setae.

Mandible—Masticatory process larger and two-lobed. Rami in older larvae appeared to be quite empty as noted by Gurney also.

Labrum and paragnatha quite prominent and behind them rudiments of the following 4 pairs of appendages are free and biramous with minute setae in larvae approaching the moult into the protozoea stage.

PROTOZOEA

Stage I.—Figs. 15-21. Length 0.67-0.74 mm

The moult from the last nauplius to the first protozoea brings about striking changes in the appearance of the larva. The anterior part of the body is now covered over by a flat and approximately oval carapace extending up to the second segment of the thorax. The nauplius eye persists and on either side of it there is a cellular

Antennule—Not quite half as long as body; 5 segments marked out proximally beyond which 2 long joints; 2 long but unequal setae and 3 aesthetes at tip and a few setae on the inner and outer sides.

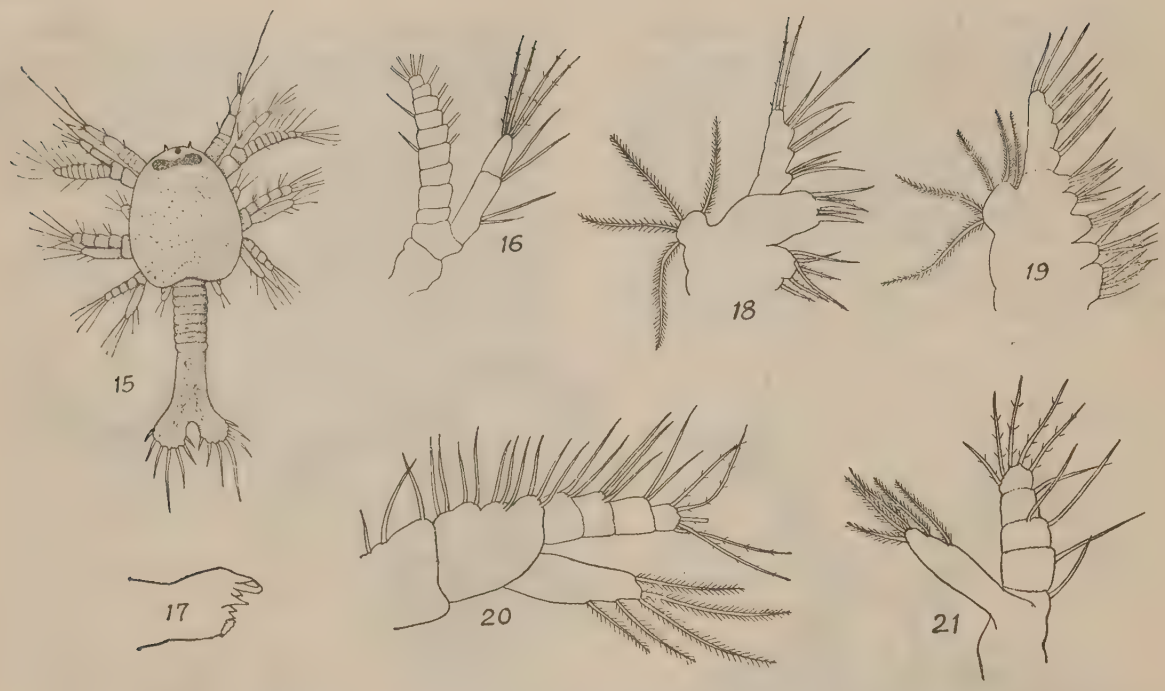
Antenna—A two-jointed protopodite, flagellum and exopodite present. Flagellum shorter, two-jointed and with 4 setae at tip and 2 pairs proximally. Scale with 9 segments; 9 plumose setae along inner margin and tip and 2 on outer margin on segments 4 and 6.

Mandible—Consists only of masticatory portion, the 2 rami having disappeared during the moult.

Labrum is prominent and bears a small forwardly directed spine.

Maxilla 1.—Consists of a basal portion produced into 2 endites, each with a number of short setae, a papilla-like exopod carrying 4 plumose setae and a faintly three-jointed endopod.

Maxilla 2.—Protopodite produced inwards into 5 endites, each armed with several setae. Exopod similar to that of maxilla I and carries 5 plumose setae; endopod four-jointed, each joint having 2-3 setae.



FIGS. 15–21. Protozoea stage 1:
15. dorsal view; 16. antenna; 17. mandible; 18. maxilla 1;
19. maxilla 2; 20. maxilliped 1; 21. maxilliped 2.

Maxilliped 1.—Fully developed and biramous, protopodite having several setae along inner margin. Exopodite shorter than endopodite with 3 terminal and 2 outer setae; endopodite four-jointed.

Maxilliped 2.—Similar to the first, but with much fewer setae on proto and endopodites.

Maxilliped 3.—Small, biramous rudiment with 2 setae at the tip of outer branch.

No other appendages are present.

Telson has 2 lobes, separated by a wide notch, each lobe having 7 setae, 4th from the outer side being the longest.

Unlike the nauplius, the protozoea feeds actively. In the laboratory they thrived well on diatoms and other forms of phyto-plankton mixed with microscopic animal forms which could not be separated.

Stage II.—Fig. 22. Length 0.81-0.98 mm

One of the most important advances which this stage shows over the first is the presence of well developed movable stalked eyes completely free from the carapace. Between them the median eye is still clearly visible. The anterior portion of the carapace is prolonged forwards between the eyes into a broad process which abruptly narrows into a short pointed rostrum. In older larvae there is a pair of small supraorbital spines, which in others are easily missed. Behind the thorax all abdominal somites except the last, are distinctly marked out. The telson remains unchanged with the same spine formula, namely 7 + 7. The appendages do not show much difference from those of the first except for the addition of one or more setae in some, as for example in the exopodites of the first and second maxillipeds which have now 7 and 6 setae respectively. Both branches of maxilliped 3 are approximately equal in length, the inner of which is unjointed and unarmed and the outer tipped with 3 setae. Small knoblike rudiments of the remaining 5 pairs of thoracic appendages are also present.

Colouration.—In addition to those noted in Stage I similar chromatophores have developed on the posterior surface of the ocular penduncles, labrum and ventrally in the region of the maxillipeds.

Stage III.—Figs. 23-25. Length 1.6 mm

The sixth abdominal segment is now cut off from the telson and the uropods have developed. The first 5 have small median spines dorsally and the fifth has a pair of lateral spines as well. The sixth segment has 2 pairs of lateral spines, a small dorsolateral pair and a slightly larger ventrolateral pair. Telson is unchanged with the same spine formula namely 7 + 7. In *Penaeus*, *Penaeopsis*, *Parapenaeus* and *Trachypenaeus* the spine formula is 8 + 8 so that in this respect *Metapenaeus* differs from the other genera of the Penaeinae. Nauplius eye is still visible and both the rostrum and supraorbital spines have grown.

Colouration.—Most of the chromatophores noted in stage II have grown larger and become branched, especially those on the telson. New ones have appeared in the middle of each abdominal somite and the exopodites of the uropods.

Antennule—Basal segmentation is hardly visible so that the appendage seems 3-jointed.

Antennae, mandibles and the 2 pairs of maxillae much as they were in the previous stage.

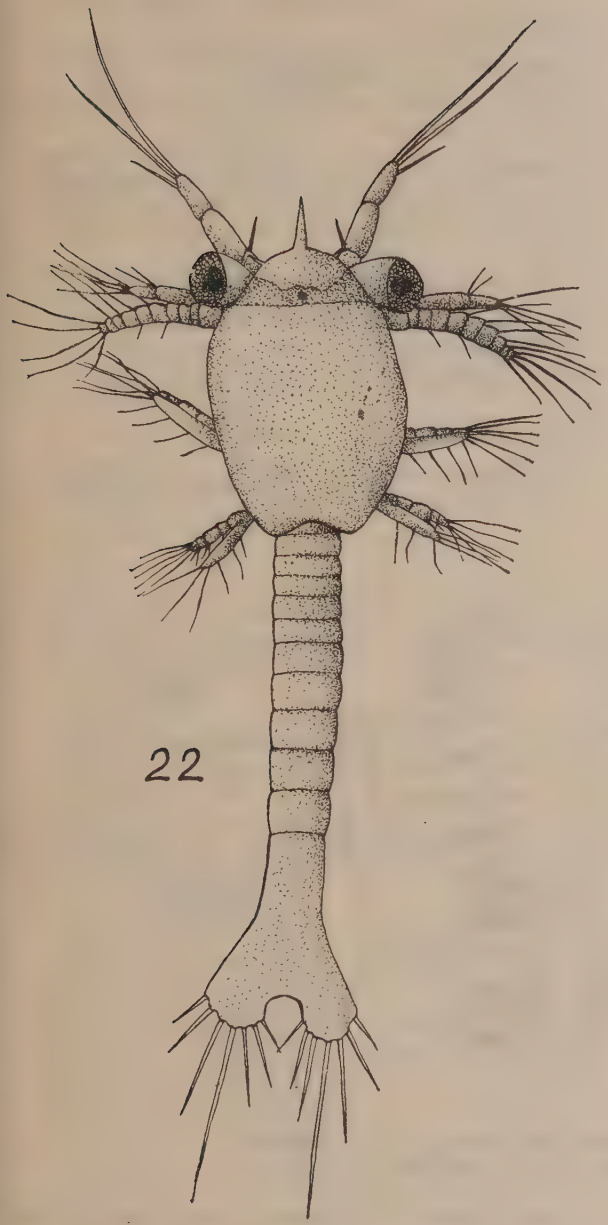


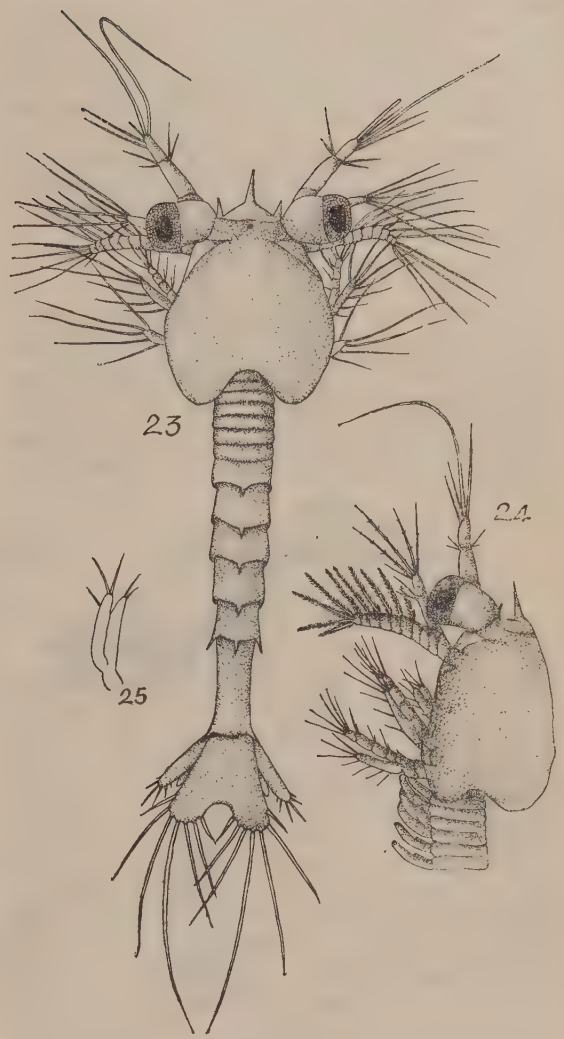
Fig. 22. Protozoea stage II.

Maxillipeds also unchanged except the third pair in which the endopod also tipped with a couple of setae.

Rudiments of the remaining 5 pairs of thoracic appendages are quite prominent and biramous, but unjointed and not functional.

Pleopods absent.

Uropods well developed and biramous; exopod slightly longer than endopod, with 6 short setae at extremity, the outermost and innermost of which are almost spinelike.



Figs. 23-25. Protozoea stage III:
23. dorsal view; 24. side view; 25. maxilliped 3.

ZOEA (Mysis).

While discussing the nomenclature of the different stages in the larval development of Decapoda, Gurney (1942) has pointed out the inappropriateness of the term Mysis. He has remarked that "it is an unfortunate term, implying a false relationship and it is not easily definable. Referring as it does to a stage with biramous legs, it cannot legitimately be applied to a stage with no exopods, although that stage is precisely equivalent to a Mysis stage in other forms. Furthermore, if the term is really used, as it has been, to imply a phylogenetic meaning, it should be applied to a stage in which the thoracic legs are free from the carapace, since thia is a much more fundamental feature of the Mysidacea than the possession of exopods". He has suggested the term zoea instead and it is used here.

The moult from the last protozoea to the zoea brings about a striking change in the shape of the larva which now assumes that of the adult prawn. Besides the change in shape, the functional development of the exopodites of all the 5 pairs of walking legs and the appearance of the pleopods (in the later stages) are the other important advances of the zoea over the protozoea.

Colouration.—The colouration is similar to that of protozoea III. The pigment spots on the abdominal segments have begun to branch and in the later stages appear like vertically arranged plates forming one of the distinguishing features of the species.

Stage I.—Figs. 26-33. Length 1.8-2.3 mm

The rostrum reaches to the middle of the cornea of the eyes and bears no teeth ; a short distance behind its base there is a small median papilla. A small antennal spine and a much larger pterygostomian spine behind the base of the antenna are present. Abdominal segments 5 and 6 have small median dorsal spines, an anal spine arises close to the margin of the last segment. Labral spine and the nauplius eye are still present.

Maxilliped 1 and 2.—Hardly any change from those of Protozoea III.

Maxilliped 3.—Endopodite 5-jointed ; exopodite with setae at tip and functional.

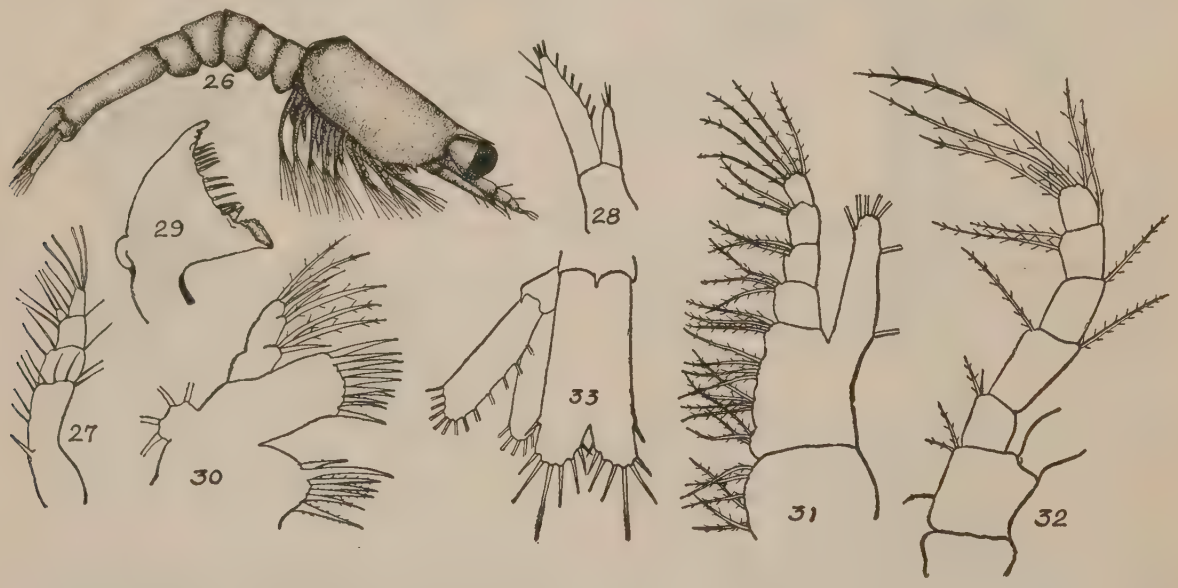
Legs 1-5.—Small and indistinctly segmented with functional exopodites.

A small gill present at the base of each of the first 4 legs. The development of gills at this stage seems rather precocious when compared to the Suez Canal larvae in which they develop only in the last zoea. Pleopods absent.

Telson and Uropods—Telson roughly parallel-sided with the posterior margin deeply cleft ; spine formula 8+8, one on each side being on the outer margin. Basal segment of uropod with a small, curved outer spine. Exopodite and endopodite both setose, but without spine on the outer margin of the former.

Stage II.—Figs. 34-36. Length 2.4-2.8 mm

Rostrum has 1 tooth dorsally. Antennal and pterygostomian spines as well as spines on abdominal somites



Figs. 26-33. Zoea stage I :
26. side view ; 27. antennule ; 28. antenna ; 29. mandible ;
30. maxilla 1 ; 31. maxilliped 1; 32. maxilliped 3 ;
33. uropod and telson.

Antennule—A peduncle consisting of 3 clearly marked segments and 2 unjointed flagella, the inner of which is small and knoblike. A prominent spine present on the inner side of the basal segment. No statocyst.

Antenna—Flagellum unjointed and about half as long as scale with 2-3 short setae at tip. Scale has 9 setae along inner margin and extremity, but no spine ; 2 setae on its outer margin.

Mandible—Slightly asymmetrical, the number of serrated spines on one side being more. A rudimentary palp present.

Maxilla 1.—Similar to that of the last protozoea.

Maxilla 2.—Similar to that of protozoea III but number of setae, especially on exopodite, more.

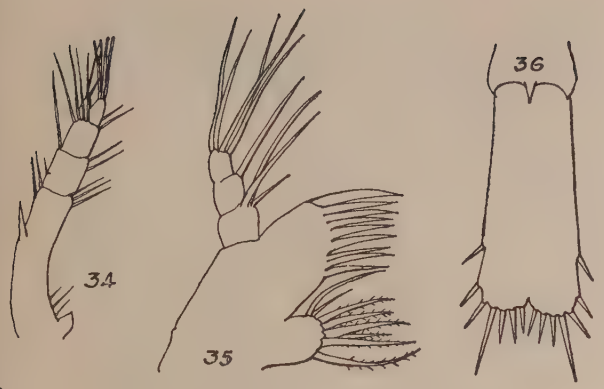
5 and 6 present as in previous stage. Small hepatic spine and pleopod rudiments have developed. Nauplius eye persists.

Antennule—A rudiment of the stylocerite in the form of a thin triangular process present ; but the statocyst has not developed. Flagella equal in length to the third joint of peduncle and unjointed.

Antenna—Flagellum still unjointed and about half as long as scale ; the latter with 15 setae along inner margin and tip and a spine.

Mandible—Palp slightly larger.

Maxilla 1.—Exopodite completely absent ; but endopodite still jointed.



FIGS. 34-36. Zoea stage II:
34. antennule; 35. maxilla 1; 36. telson.

Maxilla 2.—Scale has 12-13 plumose setae.

Maxillipeds 1-3.—Similar to those of stage I.

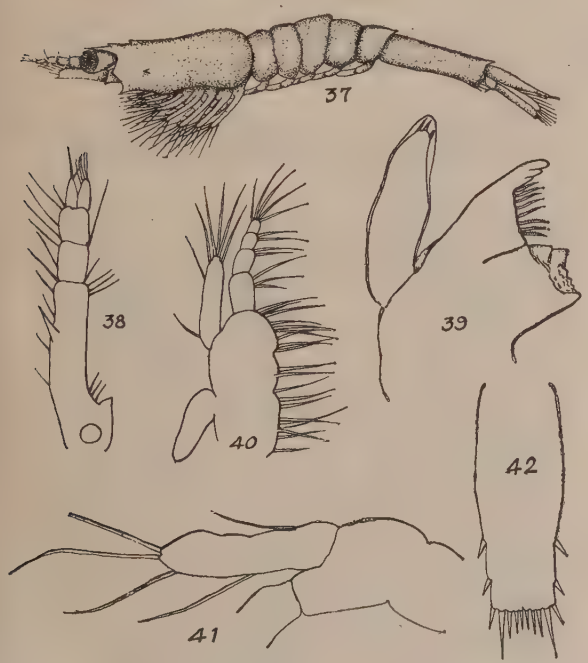
Legs 1-5.—First 3 minutely chelate.

No additional gill.

Telson and uropods.—Median cleft on posterior margin of telson quite small; only 7 spines on each side, 2 of which are on outer margin. Uropods not much changed.

Stage III.—Figs. 37-42. Length 3.3 mm

Rostrum has 2 dorsal teeth, one of which is some distance behind orbit, the other level with it. All other



FIGS. 37-42. Zoea stage III:
37. side view; 38. antennule; 39. mandible; 40. maxilliped 1; 41. leg 1; 42. telson.

spines on carapace and abdominal somites of previous stage still present. Nauplius eye persists. Pleopods are large and jointed, but uniramous and without setae.

Antennule—A well developed statocyst at the base of the peduncle. Flagella still unjointed.

Antenna—Flagellum with one segment at base and another at tip.

Mandible—Palp grown fully, but not jointed.

Maxillae 1 and 2—Show little change.

Maxilliped 1—A fairly large epipodite has developed.

Maxillipeds 2 and 3—Practically unchanged.

Legs 1-5—Large and jointed.

Number of gills remains the same.

Pleopods—Large, bent forwards and distinctly segmented, but not functional.

Telson—Shape of telson slightly different from that of stage II and this shape is retained in the early post-larval stages. Cleft on the posterior margin hardly visible. Two pairs of spines on lateral margins and 10 posteriorly.

Uropods.—Exopodite with a spine and 16-17 setae; endopodite also has an equal number.

POST-LARVAE

Stage I.—Figs. 43-50. Length 3-3.5 mm

The moult at the close of the zoea stage brings about two striking changes in the organization of the animal, namely the loss of exopodites from the thoracic appendages and the development of setae on the pleopods so as to make them functional and the chief natatory organs of the young prawn. According to Burkenroad this is usual in the subfamilies Penaeinae and Sicyoninae. In this species they do not completely disappear, degenerated stumps persisting in some individuals.

Rostrum has the same number of teeth as in the last zoea; in older individuals an extremely minute tooth also in front of the other two. A small somewhat triangular antennal spine is present; but the anterolateral angle of the carapace is not produced into a distinct pterygostomian spine. Hepatic spine quite conspicuous. Median dorsal spine only on the last abdominal somite, anal spine absent. Spine on labrum also absent; but on ventral surface of seventh thoracic somite a large forwardly bent spine has developed. Pleopods, though uniramous, are setose and functional.

Antennule—Differs but little from that of last zoea.

Antenna—A small spine on protopodite. Flagellum almost as long as scale, 4-jointed. Scale with 24-25 setae and a spine.

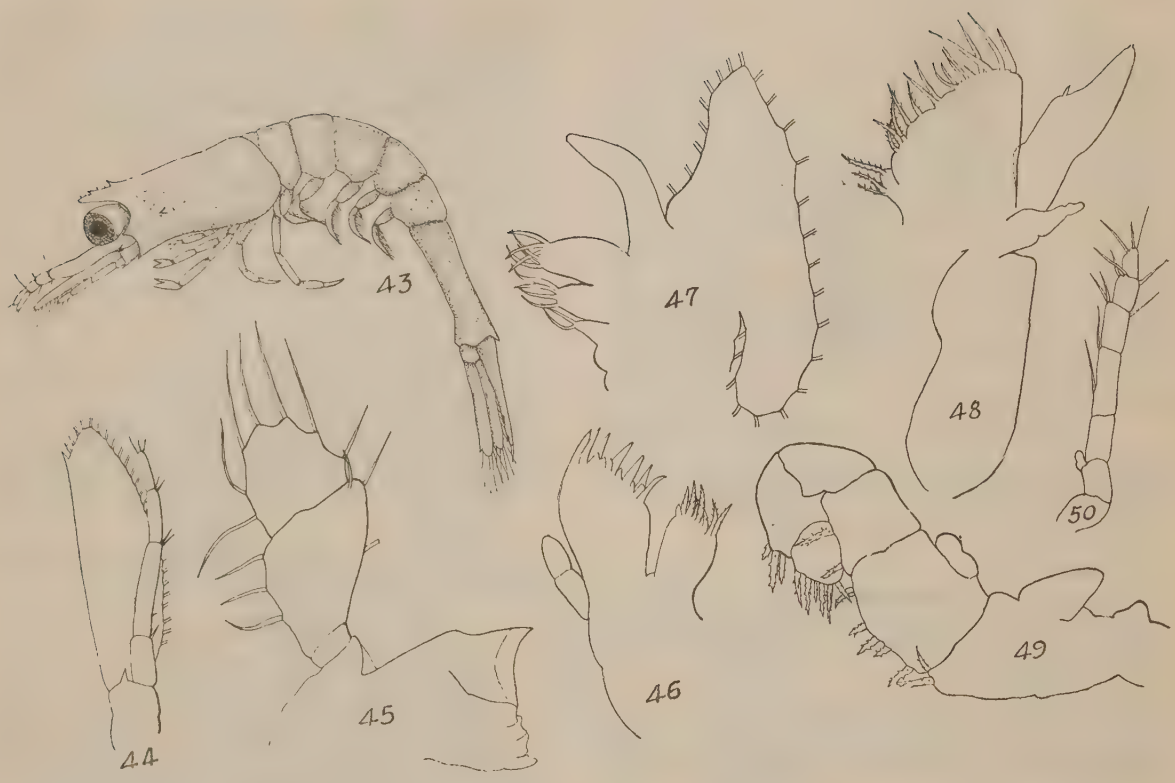
Mandible—Palp well developed, jointed and fringed with setae.

Maxilla 1—Endopodite considerably reduced in size, but faintly segmented and without setae.

Maxilla 2—Only 3 functional endites, the proximal endite of the zoea persisting as a degenerate lobe without setae. Palp unjointed and unarmed. Scale with numerous plumose setae.

Maxilliped 2—Epipodite and a small gill rudiment have appeared. Endopodite bent as in the adult.

Maxilliped 3—Neither epipod nor gill visible.



FIGS. 43-53. Post-larva stage I :
43. side view; 44. antenna; 45. mandible; 46. Maxilla 1:
47. maxilla 2; 48. maxilliped 1; 49. maxilliped 2;
50. maxilliped 3.

Legs 1-5—All jointed and functional. None with epipods; only 4 pleurobranchs as in zoea stages. Minute spines have developed on basipodites of first 3 pairs.

Pleopods—Exopodites fringed with numerous setae; endopodites absent.

Telson—Changed very little.

Post-larvae, older than the one described, were absent from plankton, although a large number of samples collected from close to the shore up to 12-13 fathoms were examined in the course of over an year. This contrasts markedly with the corresponding stages of *P. carinatus* and *P. indicus* which are frequently captured in the tow-net not only from the sea, but also from estuaries and backwaters connected with the sea. Presumably they go down soon after the moult into the second stage and adopt the bottom living habit.

In order to trace the successive changes brought about by each following moult on some of the structures which differ markedly from those of the adult like the rostrum, pleopods and telson, a few first stage post-larvae were reared separately in finger bowls and at every moult the shed skin was removed and examined. The moulting always happened at night so that the skins could be examined only the next morning. This method was adopted because of the difficulty of rearing a large number of specimens in order that one or two may be killed and examined at each moult. Despite its imperfection the method yielded a fairly good picture of their gradual development until they acquired the adult form.

These observations were started on 22-6-50 with 4 individuals obtained on that day from the last zoea stage. Moulting occurred at intervals of 2 days at first, but subsequently the periods became somewhat irregular. The dates on which one of the specimens moulted are given below :

1950, June 23, 25, 27 July 2, 5, 9, 11, 20

This specimen died shortly after the last moult. Another individual which had passed into the same stage on 21-7-50 moulted on 25-7-50, 28-7-50, 2-8-50, 4-8-50, 9-8-50 and 13-8-50. As the parts mentioned above had acquired the adult characteristics at this stage no attempt was made to follow the moults regularly thereafter. Their gradual development during this period of approximately a month and 3 weeks is briefly summarised below :

Post-larva II—A minute third tooth on rostrum; pleopods and telson unchanged.

Post-larva III—3 well developed teeth on rostrum; pleopods and telson unchanged.

Post-larva IV—Rostrum broken; pleopods unchanged; telson considerably narrower posteriorly; spines on its posterior margin between the large ones at the angles quite small.

Post-larva V—Rostrum missing; pleopods unchanged; telson as in stage IV.

Post-larva VI—Rostrum with 4 large and 1 minute teeth; pleopods unchanged; between large spines of telson a pointed triangular process has developed, on either side of which the remaining spines have become considerably reduced.

Post-larva VII—Figs. 51-52. Rostrum with 5 teeth and the dorsal crest characteristic of the adult just developed; minute knoblike endopodites with setae on pleopods 2-5; posteromedian process of telson larger.

Post-larva VIII—Rostrum with a point-like 6th tooth; endopodites of pleopods as fingerlike processes; posteromedian process of telson reaches almost to extremity of large spines, the smaller ones reduced to mere points. Antennal flagellum about two and a half times as long as scale.

Post-larva IX—Rostrum with 6 fully developed teeth, endopodites of posterior pleopods about half of exopods; posteromedian process of telson just projects beyond tips of large spines; antennal flagellum about four times as long as scale.

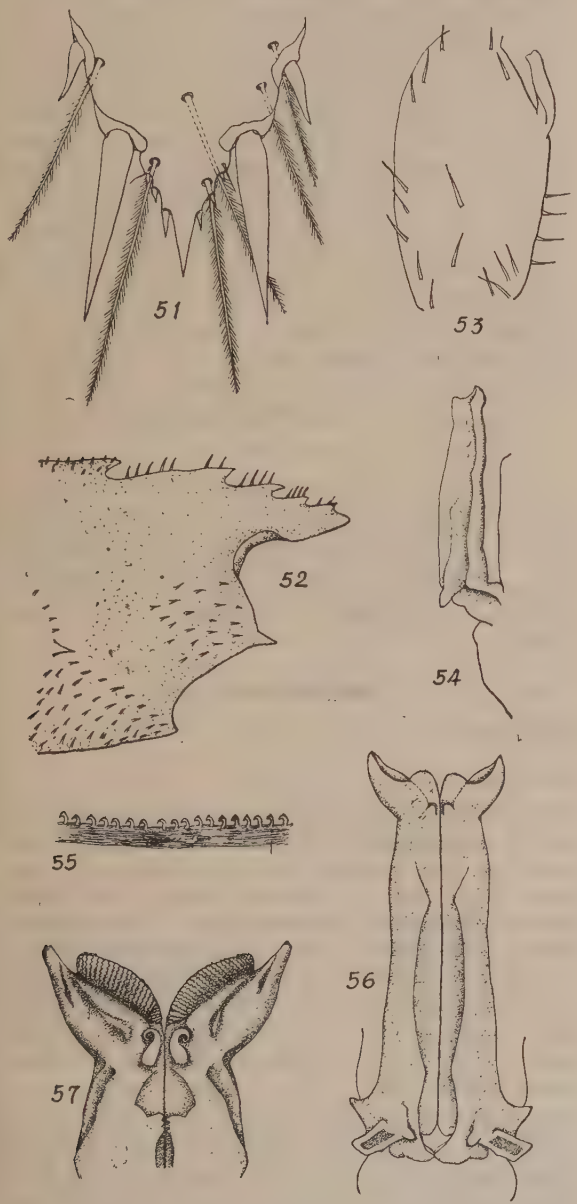
Post-larva X—Rostrum with a pointlike 7th tooth; endopodites of pleopods prominent and fringed with several setae; posteromedian process of telson much the same as in last stage; antennal flagellum stretches backwards up to the middle of telson.

Post-larva XI—Rostrum with 7 teeth; pleopods as in last stage; posteromedian process of telson longer and the two large spines of previous stages reduced; a small thin process has developed on the protopodite of the first pleopod, which is the rudiment of the petasma.

Post-larva XII—Rostrum with a minute 8th tooth; large spines on either side of the median process of telson hardly larger than anterior lateral teeth; antennal flagella stretch considerably beyond tip of telson; rudiment of petasma larger.

Post-larva XIII—Rostrum with 8 fully developed teeth; endopodites of pleopods and petasmal rudiments have grown slightly; lateral teeth of telson hardly visible.

The number of teeth on the adult rostrum is never more than 8. Starting with 2 in the first post-larva, the full number is therefore established in the course of a succession of 12 moults.



FIGS. 51-52. Post larva VII:
51. extremity of telson; 52. anterior portion of carapace.

FIGS. 53-57. Development of petasma:
53. rudiment of petasma developing on protopodite of pleopod 1;
54. the same has become grooved; 55. hooks on anterior margin;
56. lobes of petasma united; 57. extremity of adult petasma, anterior view.

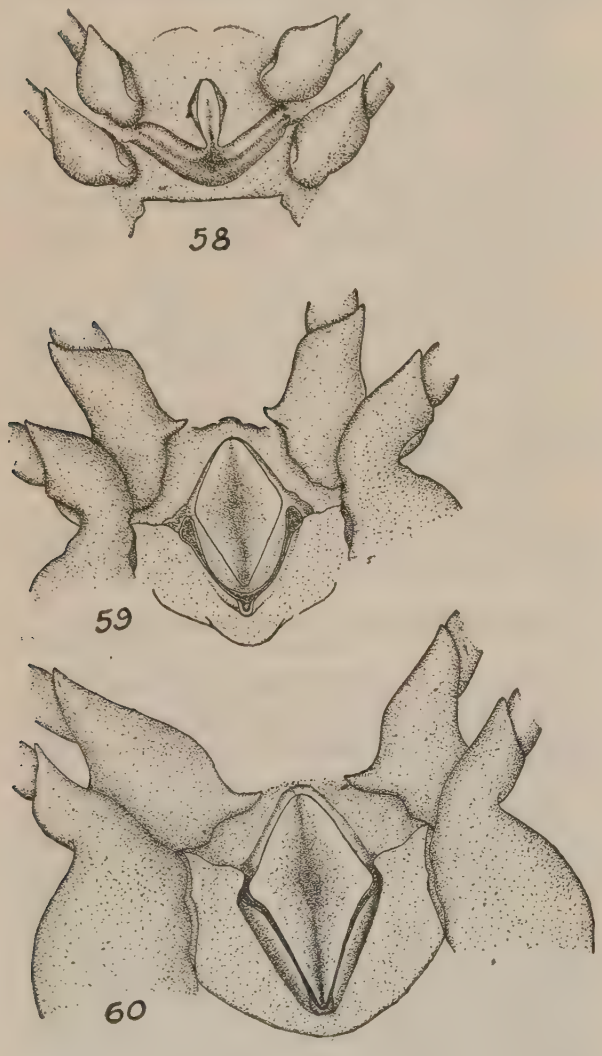
DEVELOPMENT OF EXTERNAL SEXUAL ORGANS

The petasma or andricum and the thelycum (receptaculum seminis) of the male and female respectively afford easily recognizable characters of taxonomic value and a brief account of their development is therefore added below:

Petasma.—Figs. 53-57. It is made up of 2 halves, each borne by the protopodite of the first pleopod. As noted already it develops as a short thin foliaceous process from about the middle of the protopodite in the 11th post-larval stage when the animal is slightly over 15 mm in length. It gradually grows during succeeding moults and at the same time its margins turn inwards so as to form an open groove. The outer part of its tip is gradually produced into a spout-shaped process called the distolateral lobe by Burkenroad (1934 b). At the same time the anterior margin of each half develops minute hooks all along its length. At first the hooks are arranged in a single row, those towards the extremity being separated by wide intervals. As growth proceeds additional rows are developed in the proximal part while those situated distally are closely arranged. These interlock and give rise to an incom-

plete tube open behind through the space left between their posterior margins. The distolateral lobes are also open. This happens usually when the young prawn is 50-60 mm. Some time before this the anterior margin of the spout develops a small flap or lobe at the inner end. It gradually extends along a good part of the length of the spout and the surface becomes corrugated. The space inside each spout, which was open, is closed by the growth of its posterior margin. Two pairs of papillae are developed at the base of the spouts, one pair anterior and the other posterior in position. The former are stout with curled-up tips, the latter thin and leaflike. In prawns of about 65 mm the petasma is completely developed.

Thelycum.—Figs. 58-60. The earliest stage in development was not obtained, but in a specimen measuring approximately 25 mm there is a broad roughly crescentic groove running transversely across the anterior part of the sternum of the last (XIV) thoracic segment. Laterally it stretches up to the base of the last two pairs of legs. On the sternum of the penultimate segment (XIII) there is a median elongated process, its lateral margins posteriorly becoming continuous with the front margin of the groove. This is the 'median tongue' referred to by Alcock (1906) and gives rise to the median plate of the adult thelycum. From its position it appears to be formed by the enlargement of the median spine noticeable in early post-larvae. Later it broadens out ventrally into a conspicuous, approximately quadrilateral plate with the concave surface connected with the sternum by a narrow dorsal part. At the same time the posterior margin of the groove grows and forms a flap or hood enclosing its cavity. It extends on each side from the middle line and gradually overlaps the lateral portions of the posterior half of the median plate, its anterior ends being partly concealed under the lateral margins of the front half of the latter. This is the 'salient horse-shoe shaped process' described by Alcock as ensheathing posteriorly the 'Median tongue'. The inner ends of the two hoods eventually meet along the median line so that there is hardly any gap left between them and the median plate as in *M. brevicornis* Burkenroad (1934b), through which spermatophores could be inserted at the time of copulation. In the fully developed thelycum seen in prawns of approximately 60 mm in length the anterior opening of the groove on each side is blocked in front at the level of the front end of the median plate by a short stout spine arising from the coax of the fourth leg. No part of the cavity of the groove is dilated as in other genera though the front end of each side is wide and the lateral portions are continuous in the middle line.



Figs. 58-60. Three developmental stages of thelycum: 58. groove on sternum XIV just formed; 59. hood growing from its posterior margin; 60. hood practically covers up the groove.

BIONOMICS

Breeding.

(*a*) *Place*

Penaeid prawns, with the exception of *M. stebbingi* and *M. monoceros*, breed, as far as is known, only in the sea. *M. stebbingi* has been observed to breed in the Bitter Lakes of the Suez Canal and *M. monoceros* in the shallow coastal lakes of New South Wales (Dakin, 1946). So far as present observations go, *M. dobsoni* seems to breed mainly in the sea. In discussing the habits of the species of Metapenaeus living in the Chilka lake Kemp (1915) states: 'I think it improbable that any of them breed in the lake'.

Eggs and larvae have been so far collected only in the sea though early post-larvae attributed to *Metapenaeus monoceros* have been recorded from brackish-water (Panikkar & Aiyyar 1939). Further, samples of plankton collected from brackish water areas where the adults are found throughout the year, for example the backwaters of Adyar and Kerala, have failed to show any larvae or eggs. These two facts strongly suggest the sea as the breeding place of this species.

Study of adult prawns has also yielded reliable evidence in its support. While mature males with

well developed spermatophores have been frequently collected from brackish water, no female, either impregnated or with ripe ovary, has so far been obtained from the same areas. Sexual union and ripening of the female gonad seem to take place only in the sea. Adult females from the sea have invariably the fifth pair of legs reduced to stumps. Kemp noted that in every female obtained from the Chilka lake these legs were of normal length. Commenting on this he remarks: 'It appears to me highly probable, as has already been suggested by Nobili, that the degeneration of these limbs is in some way connected with reproduction and, if this should prove to be the case, the condition of the Chilka specimens lends support to the view, based on other evidence, that this species at any rate does not breed in the lake'. However, the possibility of some of them breeding in environments similar to those in which *M. monoceros* is reported to breed cannot be ruled out altogether.

(*b*) *Period*

The breeding period seems to be fairly long as evidenced by the presence of larvae in plankton from September to April. The maximum number was obtained from November to March. Eggs occurred in plankton in fair numbers from September to the middle of January, after which the number dropped abruptly, none being obtained on several days. Plankton samples up to January contained mostly larvae of this species and in all probability therefore most of the eggs also should belong to the same. From both sets of observations it would seem that the period September to December or January forms the peak of the spawning season.

(*c*) *Area*

Details of the localities and method of making plankton collections have been already given. The offshore collections, contained very few penaeid larvae and practically no eggs. None has been made between this and the 12-13 fathoms region so that their distribution in this area is unknown at present. Basing our conclusions on the data available it may be stated that a good number of breeding females liberate their eggs in the inshore waters up to or slightly beyond the 12-13 fathoms line. In making this statement the effect of currents on the distribution of eggs and larvae has been left out of consideration owing to the lack of any information regarding them. Judging from the known distribution of planktonic eggs and larvae Pearson (1939) and Anderson and co-workers (1949) conclude that spawning of *P. setiferus* is done usually in offshore areas of the South Atlantic and Gulf Coasts of the United States of America. Dakin (1938) has stated that *P. plebejus* of Australia breeds in ocean water well out of the estuaries. The Indian species apparently differs from them inasmuch as it spawns in the comparatively shallow inshore waters.

Sexual union.

Impregnated females have been obtained practically throughout the year, the largest number being in the months of August to January and this period roughly coincides with the peak of the breeding season. Females, soon after sexual union, can be easily recognized because of the pair of prominent white pads that cover the surface of the thelycum. Each pad is completely formed in the vas deferens and can be found together with the spermatophore (occasionally 2 spermatophores, one being smaller) in the terminal dilatation of the vas deferens situated at the base of the last leg. Burkenroad (1934b) has accepted the suggestion of Kishinoye that these pads are 'perhaps rudimentary homologues of the appendages of the spermatophore of Penaeus' the function of which is stated to be 'for attachment of the exposed spermatophores in Penaeids with open thelycum'. The smallest impregnated female measured just over 65 mm.

Food.

The food of the larvae has been already described. The statement of Alcock regarding the feeding habits of adult prawns that 'they are scavengers, but many are carnivorous in a better sense and several species prey upon marine larvae and microscopic algae' is true of young ones as well. Small post-larvae thrived well on plankton containing a good proportion of algal constituents. Later on small quantities of finely minced clam or fish muscles were given in addition to plankton. Examination of the stomach contents of numerous individuals varying in length from 21-88 mm has been carried out in order to discover the food constituents in the natural habitat of these prawns and the variations, if any, in the proportion of these constituents at different stages of growth. The food in general consists of varying amounts of organic matter mixed with sand and mud. Fragments or entire bodies of small animals and algae including diatoms compose the organic matter, of which the proportion of vegetable constituents has been found to be less in the larger individuals. In some specimens measuring 21-45 mm in length examined on 22-11-49 and 6-12-49 the stomachs were practically full of fragments of the alga *Cladophora* mixed with mud and some diatoms, no recognizable animal remains being present. Individuals measuring 65-75 mm contained only a few fragments of the same alga. The animal matter largely consists of entire or partly

digested bodies of the following groups (No attempt was made to determin their identities more exactly) :

Foraminifera, Copepoda, Nematoda, Amphipoda and Gastropoda.

Besides Cladophora a number of genera of diatoms also were frequently present. The more common of them are *Fragilaria, Coscinodiscus, Pleurosigma, Navicula* and *Cyclotella.**

Rate of Growth.

Observations on the rate of growth were carried out by rearing post-larvae in suitable glass vessels. The method adopted for rearing the earliest post-larvae has been described above. After a few days the animals were transferred into glass troughs measuring 8″ x 4½″ and finally into a large one 10″ in diameter, but of the same height. Four sets of these observations were continued long enough to make them really useful. In the first 2 post-larvae obtained from the last zoea were reared for a period of 2 months and 20 days. The bottom of the trough was covered with a thin layer of sand mixed with a little mud and some sea weed also was put in. They were fed regularly with clam meat, for which they showed a great liking. Both of them were males and measured 47 and 41 mm respectively. The initial size was approximately 3.5 mm so that the increase in length was 43.5 and 37.5 mm

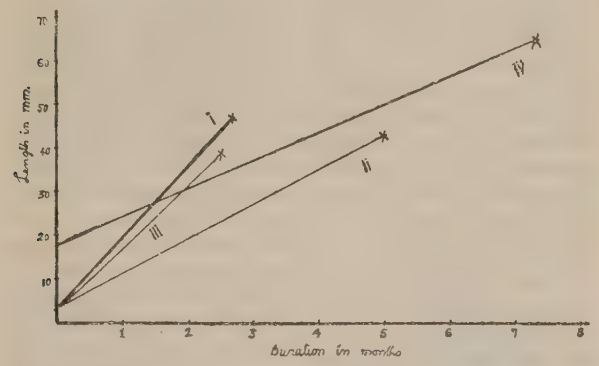


FIG. 61. Graph showing growth rates of 4 individuals in the rearing experiment.

In the 3 other experiments which were carried out at Calicut only one individual was put in each vessel. Sand and sea weeds were put in at first, but were removed later as the water was fouled quickly. The food given was finely minced fish muscle as clams were not available. Two of them were post-larvae in the first stage and the other was a young prawn measuring approximately 18 mm. In all the experiments the water was changed at least once a week. The periods through which they were reared and final size to which they grew are given below :

	Initial size.	*Period.*	*Final size.*	*Increase.*
(ii)	3.5 mm	5 mths.	43 mm	39.5 mm
(iii)	3.5 mm	2½ ,,	38 mm	34.5 mm
(iv)	18 mm	7 ,,	65 mm	47 mm

Reviewing the results of these experiments it becomes apparent that the average rate of growth has been most rapid in the first, presumably because of the optimum conditions of life provided. That in the third is comparable to the first notwithstanding some differences in environment. Taking into consideration the much longer period during which the other two specimens were reared, the average is much less. Apart from food and other factors governing growth, it is very likely that the limited space available in the vessel may retard growth markedly after a certain size is reached. Measurements of the moulted skin in the last experiment showed that in the course of the last 40 days the increase in length was only from 60 to 65 mm. Pearson (1939) also noticed ' that a limitation in maximum growth occurred quite independently of the period of confinement or the total amount of food consumed '.

Measurements of several hundreds of prawns from the commercial catches and those made for the laboratory at Calicut during the course of over an year have revealed that the dominant size groups are those between 60 and 80 mm which could not therefore be older than 7 or 8 months. During the breeding period females of 50-70 mm were found with fully ripe ovaries so that sexual maturity may also be attained at about this age.

Migration.

The observations regarding the life history recorded in the foregoing pages would make it clear that the life cycle of each individual is completed in two types of environments, namely the brackish water of estuaries and lakes connected with the sea and the sea itself. The entire course of larval development and the earliest post-larval phase are passed through in the open sea. It is not possible to state definitely where or at what size migration inwards commences. Panikkar (1937) has stated that post-larval penaeids enter backwaters when 1-2 cm in length. As has been mentioned already all available evidence goes to show that soon after the moult from the first post-larval stage the young ones cease to be pelagic. The smallest captured from brackish water at various localities are 15-25 mm in length. Prawns of this size were caught in fair numbers from the foreshore waters at West

* I am indebted to my colleague, Dr. R. Subrahmanyan, for their identification.

Hill, Calicut, up to a depth of 4 fathoms in November and December. Later there was a fall in number, but they continued to appear in the catches up to the end of April. It is quite probable that migration from the sea takes place when the young have reached this size and that successive batches pass out of the sea during the greater part of the breeding period (see also Panikkar 1937). The maximum size of prawns collected from backwaters and estuaries, as stated already, does not exceed 80 mm. Kemp records that specimens from the Chilka lake examined by him did not exceed 75 mm. The backward migration into the sea may take place soon after the monsoon rains start, the prawns being carried in the current flowing into the sea. As the largest individuals measure as much as 120 mm and have been found only in the sea they do not seem to leave the sea afterwards and re-enter their former habitat. Kemp also has arrived at the same conclusion in regard to the penaeids of the Chilka lake. It may be of interest to mention here that the investigation on the osmotic regulation in *M. monoceros* has demonstrated its high adaptability to water of varying salinity (Panikkar and Viswanathan 1948). Presumably this power is shared by *M. dobsoni* and other migratory penaeids.

SUMMARY

The larval development of *M. dobsoni* resembles closely that of *M. stebbingi* having the same number of stages and numerous common characters. Rostrum, telson and pleopods have been observed to acquire approximately adult character in the course of 12 moults. The species breeds mainly in the sea in comparatively shallow inshore waters and the period is fairly long, extending over 5-6 months. The food of larvae and early post-larvae consists chiefly of plankton; they later become bottom-feeding in habit, their stomach contents showing a good proportion of mud and sand. Considerable quantities of algae are consumed when available. Sexual maturity may be reached in 7-8 months. Like some other species of penaeids, *M. dobsoni* also migrates into estuaries and brackish water areas early in life and after a period of growth returns to the sea.

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6

STUDIES ON THE GROWTH OF KATELYSIA OPIMA (GMELIN)

by

K. Virabhadra Rao*

ABSTRACT

Longevity, growth-rate, age and size at sexual maturity and period of spawning of the Venerid bivalve, *Katelysia opima*, have been studied from monthly samples collected from the Adyar estuary at Madras. The significance of deeply marked rings on the shell and the effect of fluctuations in salinity on the breeding and growth-rate are discussed.

Among the shellfish, *Katelysia opima*, which is one of the Venerid bivalves, is third in abundance after the oyster, *Ostrea madrasensis*, and the clam, *Meretrix casta*, in all the east coast estuaries and backwaters of South India. Large quantities of this clam are collected for food and as fish bait, and for its shells which form not an insignificant bulk of the material used in the manufacture of lime.

Very little information is available on the growth of the bivalve molluscs of the Indian waters. Winckworth (1931) gave a brief account of the growth of *Paphia undulata*, and Paul (1942) made observations on the growth and breeding of *Ostrea madrasensis* and *Mytilus viridis* from Madras harbour. The only investigations in this direction in the vicinity of the Indian shores were by Herdman (1903) and Malpas (1933) on the pearl oyster, *Pinctada vulgaris*, off the coast of Ceylon in the Gulf of Manaar. The opportunity presented by the temporary location of the headquarters of the Central Marine Fisheries Research Station at Madras during the years 1948-49 was availed of by the writer to attempt growth studies of this clam from monthly samples obtained from the Adyar estuary.

ENVIRONMENT, MATERIAL AND METHODS OF STUDY

The Adyar estuary within the city of Madras has no permanent communication with the sea. With the onset of the north-east monsoon when the level of the waters of the river rises due to floods, communication is established with the sea, but after an interval of a month or two, when the water-level falls, the breakers at the river-mouth lift up a bank of sand to form the ' bar ' which cuts off connection with the sea in about March. Owing to (i) the intermittent closing and opening of the bar which controls the flow of sea water into the estuary, (ii) the dilution of the waters by the floods after the rains and (iii) the concentration of salts by evaporation as a result of drought conditions in summer months, the salinity fluctuations are very marked.

Samples of *Katelysia opima* were obtained once a month from an area of 100 yards by 100 yards close to the river-mouth from January 1948 to February 1949. As the clams possess fairly long siphons, they burrow three to four inches deep into the substratum. The sandy bottom was ploughed with the feet of the person collecting the clams to feel their presence and were picked up by hand. Care was taken to see that the entire area was covered in every collection, and no unduly large numbers were gathered from any particular spot, even if such definite spots presented specially large populations. It was found (first in March 1948), that the young clams settled in the sands at the water's edge which were therefore carefully searched for every time a collection was made; and when clams occurred, they were separated from the sand with a sieve. In this way representative random samples of the population of the locality were obtained. Their length was measured, with sliding calipers, correct to one-tenth of a millimeter and they were arranged in size groups with class intervals of three millimeters. As the number of total observations varied in different months, the size frequencies were converted into percentages of the total populations, and were represented for each month by graphs and histograms, which formed the basis for the interpretation of the growth of the year classes. Monthly averages of salinity and temperature of the waters were recorded for the period of observations to study their influence on the rate of growth. Actual rate of growth in clams marked and left in the locality was observed for a few months, but the experiment had to be given up, as it was not possible to recover them, particularly after the floods. Every month a portion of the sample was examined to ascertain the condition of the gonads with a view to determining age and size at sexual maturity and period of spawning. An attempt was also made to study the significance of certain deeply marked rings, characteristic of the majority of the shells collected from the locality.

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TABLE I

Showing the No. and Percentage Frequencies of clams of different size groups for various months

Size groups in mm	January 29th 1948		February 29th		March 23rd		May 22nd		June 22nd		July 10th		August 2nd		August 25th		September 23rd		October 23rd		November 24th		December 24th		January 22nd 1949		February 21st	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0- 3	..	..	..	..	6	4.1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	2.4
3.1- 6	..	..	..	..	9	6.1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	4.8
6.1- 9	..	..	..	..	6	4.1	..	..	..	..	1	0.7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
9.1-12	..	..	..	..	3	2.0	6	5.6	8	6.3	3	2.2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1.2
12.1-15	..	..	..	..	16	10.8	5	4.7	8	6.3	10	7.5	6	2.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..
15.1-18	..	..	..	..	4	2.7	9	8.5	15	11.8	20	15.9	8	3.9	4	2.6	..	..	7	6.08	..	..	..	..	1	1.08	..	..
18.1-21	..	..	..	..	4	2.7	9	8.5	19	14.9	17	12.7	24	11.6	14	9.2	2	1.5	13	11.3	..	..	2	1.9	..	..	..	..
21.1-24	2	1.4	..	..	2	1.36	22	20.7	16	12.6	19	14.1	29	14.4	21	13.8	15	11.2	13	11.3	2	2.3	6	5.7	2	2.17	..	..
24.1-27	1	0.7	2	2.9	4	2.7	20	18.8	11	8.4	13	9.7	7	3.5	21	13.8	13	9.7	5	4.3	15	17.1	6	5.7	4	4.3	..	..
27.1-30	17	12.1	2	2.9	1	0.7	6	5.7	5	3.9	9	6.6	27	13.4	21	13.8	21	15.7	25	21.7	22	25.0	21	20.0	18	19.6	2	2.4
30.1-33	49	35.0	22	31.4	15	10.2	4	3.7	11	8.4	9	6.6	30	14.9	39	25.6	50	37.3	30	26.1	21	23.9	47	44.7	37	40.2	13	15.5
33.1-36	36	25.7	34	48.5	51	34.7	2	1.9	4	3.1	5	3.7	11	5.4	9	5.9	20	14.9	6	5.2	11	12.5	16	15.2	16	17.4	18	21.4
36.1-39	25	17.9	8	11.4	17	11.6	11	10.4	8	6.3	6	4.5	19	9.4	6	3.9	4	2.9	4	3.5	8	9.1	3	2.9	7	7.6	28	33.3
39.1-42	7	5.0	..	..	8	5.4	10	9.4	17	13.4	16	11.9	26	12.9	11	7.2	8	5.9	9	7.8	5	5.7	3	2.9	5	5.4	10	11.9
42.1-45	3	2.1	1	1.4	1	0.7	2	1.9	5	3.9	6	4.5	11	5.4	4	2.6	1	0.75	3	2.6	4	4.5	1	0.9	1	1.1	2	2.4
45.1-48	..	..	..	..	..	..	..	..	..	..	..	..	4	1.9	2	1.3	..	..	..	..	..	..	..	..	1	1.1	3	3.6
48.1-51	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1.2
51.1-54	..	..	1	1.4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	140		70		147		106		127		134		202		152		134		115		88		105		92		84	
Min.	21.8		25.1		2.5		9.8		11.0		8.6		13.6		15.8		19.4		16.0		24.5		21.0		17.0		2.0	
Max.	44.7		52.5		43.5		44.5		43.2		44.8		47.4		46.5		43.5		45.0		43.2		44.0		47.5		51.0	
Mean	33.516		33.86		26.52		25.75		25.86		25.67		29.88		29.09		30.52		28.68		31.5		30.843		32.05		33.9	
St. Dev.	3.78		3.54		12.041		8.772		9.71		9.836		8.585		6.735		4.845		6.822		5.055		5.610		4.4697		9.747	
St. error	0.31		0.42		0.99		0.843		0.86		0.84		0.62		0.546		0.42		0.635		0.539		0.547		0.466		0.354	

PERIOD OF LIFE AND GROWTH OF YEAR CLASSES

Spawning commences in late December and lasts throughout January as shown by the occurrence of clams with spent gonads during this period. The young clams make their appearance in February and March. It is therefore presumed that the embryonic and larval life may last about four weeks. From the size-frequency graphs it is evident that the clams attain an average size of 22.5, 31.5 and 40.5 mm at the end of the first, second and third years of their lives. Most clams probably die during and immediately after the third year. Growth rate is not uniform in all the months of the year, but seems to be markedly rapid in, if not entirely restricted to, the period from January to July.

The growth of the year classes was read from the length frequency graphs (Figs. 1 and 2) for the various months from January 1948 to February 1949.

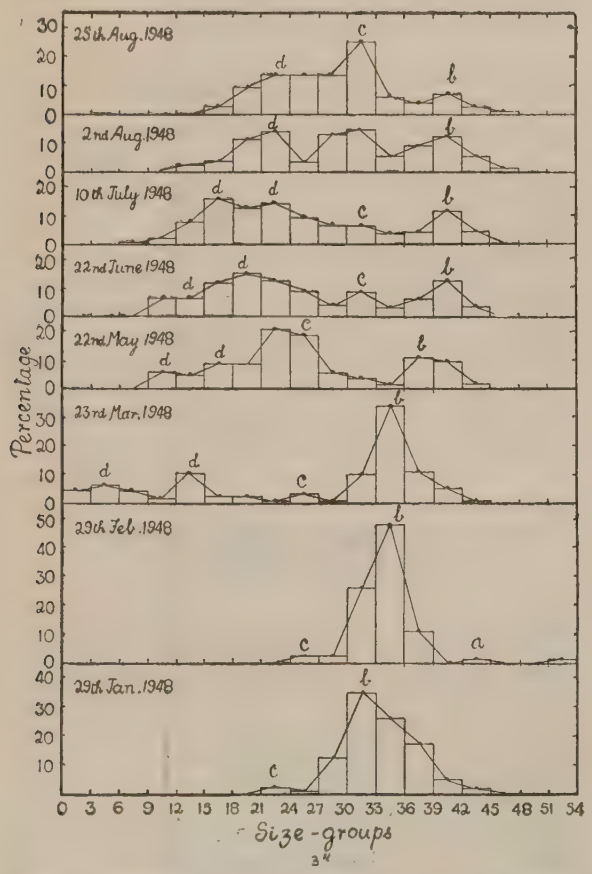

FIG. 1. Length-frequency Diagrams of Clams During Different Months. Data given in Table I. (*a.*) 1945 Year Class, (*b.*) 1946 Year Class, (*c.*) 1947 Year Class, (*d.*) 1948 Year Class and (*e.*) 1949 Year Class.

The graph for January 1948 indicates one small mode at 22.5 mm and another a prominent one at 31.5 mm. These two represent the 1947 year class (c) and 1946 class (b) respectively. From the heterogeneous distribution of the clams ranging between 28.5 and 43.5 mm there seems to be a merging of a good number of the members of 1947 year class on one side and those of 1945 year class on the other with the 1946 year class in the middle. The 1948 year class has not yet made its appearance.

In the graph for February 1948 the modal value of the 1947 year class (c) is 25.5 mm, of the 1946 year class (b) is 34.5 mm and of the 1945 year class (a) is 43.5 mm. There is still the indication of the merging of the populations of the 1947 year class and 1945 year class with 1946 year class. The new year class of 1948 must have made its appearance during this month, but was not obtained in the sample collected from the bed.

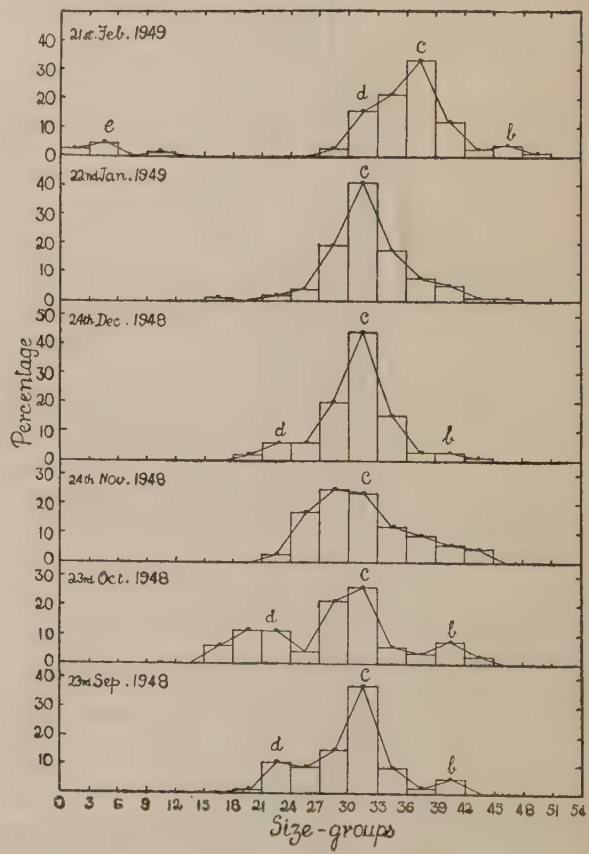

FIG. 2. Length-frequency Diagrams of Clams During Different Months (*Contd.*). Lettering as in Fig. 1.

In March 1948 it was found that the young ones settled on the sands at the water's edges and not on the beds where the adults occurred. The new year

class of 1948 (d) was then represented in the sample and shows in the graph with modes at 4.5 and 13.5 mm. From the wide range of variation of the sizes of the young clams it is evident that spawning is not simultaneous, but intermittent and prolonged over some duration of at least several weeks. The 1947 year class (c) still shows a small mode at 25.5 mm but the majority of its class has merged with those of the previous year class whose mode value remains at 34.5 mm as in the previous month. There is a decline in the members of the 1945 year class (a) which can be easily understood by the disappearance of its mode.

In the graphs of May to September 1948 the three year classes of 1948 (d), 1947 (c) and 1946 (b) are represented by distinct modes. In the graph for May 1948, the 1948 year class (d) still appears as a heterogeneous assemblage represented by two modes at 10.5 and 16.5 mm, which are at 13.5 and 19.5 mm in June, and at 16.5 and 22.5 mm in July 1948. Towards the end of August the 1948 year class assumed compactness with a mode value of 22.5 mm which remained stationary in the rest of the months of the year. The 1947 year class with its mode value of 25.5 mm in May passed on to 31.5 mm by June and remained stationary till January 1949. The 1946 year class which had a mode value of 37.5 mm in May 1948 passed on to 40.5 mm by June and remained steady till October 1948, after which it gradually diminished. This year class is still represented by a few members in February 1949 as shown by a small mode at 46.5 mm which is a repetition of events observed in the previous year (February 1948) in regard to the 1945 year class.

From August to November 1948 the gradual merging of the 1948, 1947 and 1946 year classes is clearly indicated by the graphs. In the graph for November 1948 there is a large assemblage of the members of the said three year classes with only one mode at 31.5 mm which is that of the 1947 year class.

In the graphs for December 1948 and January 1949 the distribution of the members of the various year classes is more or less the same as in November 1948. However, the percentages of clams having the mode value of 31.5 mm increase as represented by steep peaks in both the months. This is probably due to fall in numbers of the 1946 year class as a result of elimination by death, and also to the passing of some of the members of the 1948 year class into the 1947 year class. In February 1949 a fresh year class of 1949 (e) commenced its life and is represented by a few members in the sample.

To study the actual rate of growth, clams in three batches comprising 423 numbers in all were marked on the shell with water-proof Indian ink, covered with a thin film of canada balsam in xylol, dried for about an hour and put back in the waters of the estuary in an area of 6 feet by 6 feet, the four corners of which were marked by four stones to serve as landmarks for location of the place in subsequent visits for observation. Monthly measurements were taken, and after retouching the numbers with ink and balsam they were put back in the waters. The experiment, however, met with little success, as the place was frequented by fishermen, who having watched the operations on our visits used to remove the clams in our absence for fish bait. The numbers recovered month after month gradually dwindled, and finally in July 1948 when the water level in the estuary began to rise, no more clams could be recovered and the experiment had to be abandoned. Meagre though the data are (Table II), the growth rate shown by some of the individual clams is in conformity with results obtained from the size frequency method. For instance, clams with numbers

TABLE II

Showing Growth of Marked Clams *

Number marked on clam	Length of the clam in mm on				
	29-1-48	29-2-48	31-3-48	29-5-48	27-6-48
1	19.7	..	27.5	30.0	..
3	26.5	30.1	34.7	..	..
5	21.7	25.7	..	31.2	..
11	40.9	..	43.8	..	..
13	38.4	41.9	..	41.9	..
43	31.1	36.0	..	..	..
44	31.8	37.0	..	37.5	..
53	31.9	37.0	37.5	..	..
62	32.6	36.5	..	..	..
78	33.7	38.9	..	..	..
113	36.6	39.3	..	..	..
117	37.7	40.2	..	..	..
134	35.1	..	42.1	..	..
226	..	34.8	35.8	..	..
231	..	32.8	35.9	..	..
247	..	31.5	33.6	..	..
256	..	34.7	35.9	..	..
262	..	33.5	33.9	..	..
335	..	..	41.0	41.5	..
340	..	..	35.2	35.3	..
345	..	..	43.5	44.0	..
353	..	..	34.6	35.4	..
368	..	..	33.0	33.5	33.5
379	..	..	32.8	33.6	33.6
404	..	..	20.2	23.0	..
414	..	..	36.1	36.5	36.5

* Numbers 1 to 218 on 29th January, 219 to 290 on 29th February and 291 to 423 on 31st March 1948 were marked. Only those are included in the table, the growth records of which could be made.

1 and 5 which belong to the 1947 year class, measuring 19.7 and 21.7 mm in length on 29th January, 1948, pass on to 30.0 and 31.2 mm respectively by 29th May, 1948 ; and the average growth shown by the size frequency method for this year class for the period January to June is from 22.5 mm to 31.5 mm.

AGE AND SIZE AT SEXUAL MATURITY AND PERIOD OF SPAWNING

During March and April, 1948, when a large number of small clams were obtained in the samples, their gonad tissues were microscopically examined and it was found that the first indications of the motile sperms in males, and yolk-laden ova in the females were met in individuals of 11.4 and 12.0 mm. length respectively. The gonad tissue of clams from 12.5 to 15 mm. length presented the appearance of that of the large and mature individuals except for its bulk which was in proportion to the size of the individuals. As the clams of this size were found in March and April, they could not have been more than four months old from the time they started their embryonic life after the spawning of the parent stock in January. The first definite indications of sex were found in clams about two months old. Continued examination of the clams of 1948 year class in the subsequent months had shown that there was an elaboration of the gonad tissue in bulk, without any indication of spawning till January 1949, in which month the spent nature of ovaries and spermaries revealed that they had spawned for the first time. Examination of the gonads of the larger clams of 25 mm and upwards showed in 1948 partially spent or spent condition in January, and spent condition from February to April. From April onwards they showed signs of recovery and were full by August. From August to last week of December there were no indications of spawning. In a sample examined on 24th December, 1948, about 5 per cent of the clams showed partially spent gonads. Another sample examined on 22nd January, 1949, showed 80 per cent in spent condition, 17 per cent in partially spent condition, and the rest without any indications of having spawned. Thus partially spent gonads were found from December to April in varying numbers, but full gonads in smaller or larger percentages occurred in all the samples examined. Though sexual maturity is reached when the clams are about three months old, spawning does not seem to take place until they complete the first year of their life. As they generally survive for about three years, they spawn thrice during their life. Spawning is preceded by the opening of the bar and the mixing up of the sea water with the estuarine water. Mortality is very great after the third spawning. In March, 1948, when many adult clams within the range of the size groups from 30 to 45 mm long were found on the beds, either dead or in a dying condition with their valves gaping open, their gonad condition was examined and they all showed spent condition. The proportion of males (64.2) in these samples was higher than that of females (35.8.).

EFFECT OF SALINITY AND TEMPERATURE ON GROWTH AND BREEDING

Growth of the different year classes, as represented by the shifting of the mode values, together with the monthly averages of salinity and temperature of the waters of the locality are shown in Table III and Figure 3. As seen from the figure there is growth in the year 1948 from January to June in the 1946 and 1947 year classes and up to July in the 1948 year class, but practically no growth from August to December in any of the year classes. The average length attained at the end of the first, second and third years of their lives being 22.5, 31.5 and 40.5 mm, the average growth in the respective years is 22.5, 9.0 and 9.0 mm.

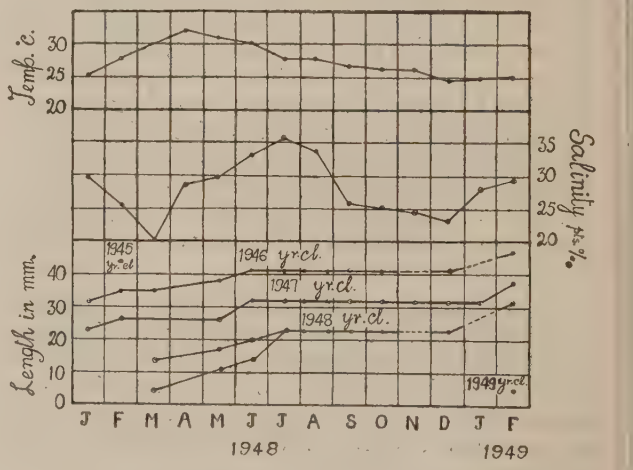

FIG. 3. Growth of Different Year Classes in Relation to Fluctuations in Salinity and Temperature. Data given in Table III.

The peculiar fluctuating environmental conditions of the estuary seem to have a bearing on the breeding and growth rate of *Katelysia*. Usually the bar remains open from December to the earlier part of February. The mixing of the sea water with the estuarine water causes the salinity of the latter to rise, at which time the clams not only liberate their spawn but also assume a rapid rate of growth. Even after the bar is closed in March, the salinity goes on increasing in the succeeding months till about July because of evaporation of water by summer temperatures. During the latter part of

TABLE III

Showing mode-values of the year classes with average salinities and temperatures in the respective months

Year classes	1948													1949	
	Jan. 29th	Feb. 29th	Mar. 23rd	April	May 22nd	June 22nd	July 10th	Aug. 2nd	Aug. 25th	Sept. 23rd	Oct. 23rd	Nov. 24th	Dec. 24th	Jan. 22nd	Feb. 21st
1945 yr. cl. (*a*) ..	..	43.5	..	..	..	..	..	..	..	..	..	..	..	..	..
1946 yr. cl. (*b*) ..	31.5	34.5	34.5	..	37.5	40.5	40.5	40.5	40.5	40.5	40.5	..	40.5	..	46.5
1947 yr. cl. (*c*) ..	22.5	25.5	25.5	..	25.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	37.5
1948 yr. cl. (*d*) ..	..	..	4.5 13.5	.. ..	10.5 16.5	13.5 19.5	16.5 22.5	22.5	22.5	22.5	22.5	..	22.5	..	31.5
1949 yr. cl. (*e*) ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4.5
Salinity o/oo ..	29.8	25.4	20.32	28.59	29.15	33.15	35.74	..	33.63	25.79	25.02	24.46	23.26	28.16	29.44
Temperature (°C)	25.2	27.8	30.26	32.25	31.3	30.1	27.95	..	27.85	26.75	26.5	26.1	24.5	24.7	25.0

July (in the year 1948 or earlier in some years) when the rain water enters the estuary, salinity, gradually falls and it continues to be low till the bar again opens in about December. The period from August to December, 1948, with a decline in salinity was marked by arrested growth as shown in Fig. 3.

The period of high salinity from April to July, 1948, coincides with high temperature. Hence it is very difficult to state whether it is high temperature or high salinity or the combined effect of both that accelerates growth during the period. That a higher salinity is the probable factor in inducing growth is shown by the fact that growth is initiated in January of both the years 1948 and 1949 when the water temperatures were low and salinities high. There is also the possibility of yet other unascertained factors being the direct cause of more rapid growth, as the occurrence of abundant supply of food organisms in the environment or the ability on the part of the clams to circulate water current more rapidly and feed better under high salinity conditions.

SIGNIFICANCE OF RINGS

The presence of a ring on the shell of a bivalve is a definite indication of cessation of growth for some period due to a physiological disturbance in its rate of metabolic activity which is usually brought about by a change in the environment. It is well-known that in lamellibranchs living in temperate waters, where the change of seasons is sharply marked by appreciable rise and fall in temperature in summer and winter months, the shells present annual rings, from which the age of the animal can be determined. Under tropical conditions, where water temperatures remain high and almost steady throughout the year, usually no annual rings are recognizable. Orton (1926) established by his experiments on *Cardium* that even a slight disturbance of the living mollusc would cause the formation of a 'disturbance ring' on the shell, the depth of the groove of the ring being determined by the period of cessation of growth. An attempt has been made to study the significance of certain deeply marked rings presented by a majority of the shells of *Katelysia* in the samples collected from Adyar. From the data presented in Table 4 it is clear that the occurrence of the rings is a regular feature, and their positions on the shell being definite they have an indication as to the age of the animal. In clams between 49 and 51 mm in length three rings are present. From the evidence we have from the size frequency graphs, the clams of this size have completed three years of life. Clams from 38.8 to 43.5 mm present two rings, and are over two years of age, but not completed their third year. Clams from 26 to 33.8 mm in length have one ring, and are of over one year, but not completed their second year of life. The respective distances from the umbo to rings 1, 2

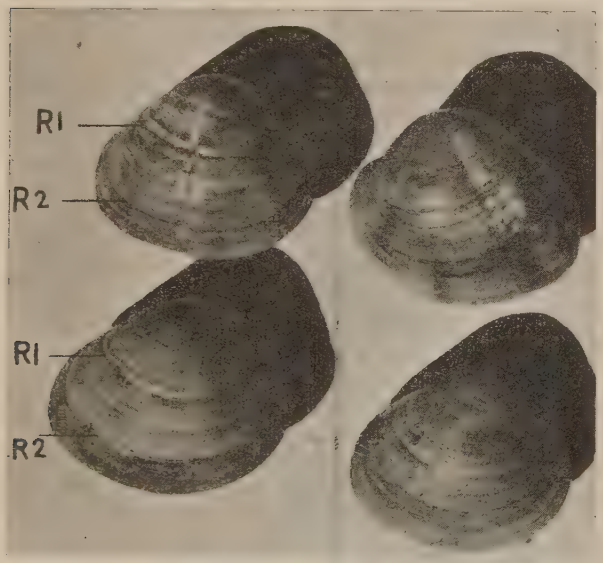

Figure 4. Photograph of Clams Showing Rings R 1. and R 2., Rings one and two. (about $\frac{3}{4}$ natural size).

TABLE IV

Showing Size of Clams with Position and Number of Rings

Length in mm	Width in mm	Number of Rings	Distance of Ring 1 from umbo in mm	Distance of Ring 2 from umbo in mm	Distance of Ring 3 from umbo in mm
51.0	43.5	3	24.0	34.0	40.0
49.0	42.5	3	22.8	33.8	39.0
43.5	37.2	2	20.5	30.2	..
41.2	34.0	2	19.0	31.2	..
43.2	38.5	2	19.9	33.8	..
42.0	35.9	2	18.5	30.5	..
41.5	36.8	2	19.5	32.0	..
42.0	37.0	2	21.5	32.8	..
40.8	35.6	2	19.8	30.2	..
40.4	35.8	2	20.0	30.6	..
42.0	35.5	2	19.0	32.0	..
38.8	32.0	2	18.5	29.5	..
38.8	32.2	2	19.5	28.0	..
33.8	29.2	1	22.0	..	..
34.5	28.5	1	21.5	..	..
31.0	25.6	1	22.0	..	..
33.0	26.6	1	22.0	..	..
31.0	26.5	1	23.0	..	..
32.0	26.2	1	22.0	..	..
31.5	26.2	1	21.5	..	..
28.2	25.0	1	22.8	..	..
26.0	22.0	1	20.9	..	..

and 3 are almost constant in the sample examined. The rings described here are of the nature of 'disturbance rings' and they seem to indicate periods of arrested growth that recur year after year from about August to December when there is a fall in salinity of the waters.

GENERAL CONSIDERATIONS

Katelysia is primarily marine and is found burrowing in sand or mud in the quiet shallow waters as in the mud-flats of Pamban, but has also secondarily invaded the backwaters and estuaries in which its distribution is confined to regions in the closest vicinity of the sea. It is never found far up the river-mouths or in the interior of the backwaters, where the salinities are low. As contrasted with this genus, the true backwater clam, *Meretrix casta*, and the black clam, *Corbula* (*Velorita*) *cochinensis*, never occur under purely marine conditions, but form extensive beds in estuaries and backwaters. These clams seem to have attained a greater tolerance to low salinity conditions than *Katelysia*. The flow of the sea water into the estuary during the period when the bar is open at Adyar provides almost marine conditions which seem to stimulate breeding activity and growth of *Katelysia*.

Most authors, e.g. Semper (1883), and Orton (1920), have described continuous breeding of marine organisms in tropics. Anne Stephenson (1934), Panikkar and Aiyar (1939), and Paul (1942), described different types of both continuous and discontinuous breeding in marine and brackishwater animals. The present writer in an earlier paper (Rao 1951) on the effect of salinity on the breeding of *Ostrea madrasensis* studied from two different localities under marine and estuarine conditions has observed continuous breeding in the former environment and discontinuous breeding in the latter. In *Ostrea madrasensis* the restricted periods of breeding in the backwaters correspond closely with peak periods in continuous breeding under marine conditions. Variations in temperature and salinity have an important bearing on the breeding, larval development and setting of spat of the Madras oyster. While in the preceding account it is indicated that the clam *Katelysia* has restricted breeding under estuarine conditions of Adyar, no attempt has so far been made to observe its breeding activity under purely marine conditions.

There being no adverse winter temperatures to retard growth, Rao (1937) has observed growth in all the months of the year in *Trochus niloticus* in the Andaman waters and Paul (1942) has observed the same in different invertebrate animals of the Madras harbour. The cessation of growth in *Katelysia* from August to December in Adyar is probably not due to any variations in temperature but to other adverse factors such as the direct or indirect effect of a fall in salinity.

Belding (1910) has shown in *Pecten irradians*, and Coe (1947) in *Tivela stultorum*, that spawning period is followed by cessation of growth. The observations of the writer on *Katelysia* that during and immediately after spawning there is a rapid rate of growth, are in conformity with similar findings of Belding (1912 and 1931) in *Venus mercenaria* and *Mya arenaria* and of Loosanoff and Nomejko (1949) in *Ostrea virginica*.

Weymouth (1923) has found in *Tivela stultorum*, and Weymouth and others (1925) in *Siliqua patula*, Sewell (1924) in *Mytilus variabilis*, and Orton (1926) in *Cardium edule*, that the annual rings are helpful in determining the age. Winckworth (1931) observed in *Paphia undulata* no regularity in the rings and concluded that the winter rings were masked by disturbance rings. There being no sharp fall in temperature of the waters in any particular season in the Madras harbour, from which the molluscs were collected and sent to him for examination, winter rings could not be expected in them, and all the rings he observed in *Paphia* were probably of the nature of disturbance rings only. There is regularity in the occurrence of disturbance rings in *Katelysia* because of the annual recurrence of the conditions that cause the formation of a ring.

Examination of the clams fished in Adyar revealed that the 'commercial catches' are not composed of individuals of any particular size. There being no size-limit and no restriction of any kind on fishing from the natural beds, clams of all sizes are indiscriminately removed from their beds in all months of the year, which, if allowed to continue, is bound to affect adversely the clam populations of the locality. If the law prohibited removal of clams of length less than 30 mm the beds would not be likely to undergo depletion due to overfishing. This size is reached in about two years, and if the fishing were held about February the clams would be given a chance to liberate their spawn before their removal from the beds. As the meat is poor after spawning, it is preferable to fish clams before the spawning season. If the size restriction were strictly adhered to, fishing could be held in the months from October to December, during which period the meat is at its best. It is advantageous to maintain certain beds closed for fishing at all times, so that the clams therein may serve as breeding reserves for populating the nearby beds.

SUMMARY

1. From observations on monthly random samples of *Katelysia opima* from the Adyar estuary near Madras from January, 1948, to February, 1949,

it is concluded that the duration of life of this clam is about three years, and that in the first, second and third years of life they attain an average size of 22.5, 31.5 and 40.5 mm in length respectively.

2. The first indications of sex are met in males when they are of 11.4 mm and in females when 12 mm in length. Sexual maturity is attained in two to three months when they are just over 12 mm long.

3. Spawning starts in late December and lasts throughout January. They spawn for the first time when they complete one year of life. Spawning commences when the bar at the river-mouth opens and sea water mixes with the estuarine water. As the duration of life is about three years, they spawn thrice in their lives.

4. Rate of growth is not uniform throughout the year. Growth seems to be confined to the period from January to July which is marked by a gradual rise in salinity. From August to December growth seems to be arrested when there is a fall in salinity.

5. The ' disturbance rings ' seen on the shells probably indicate periods of arrested growth due to fall in salinity.

The writer has pleasure in offering his sincere thanks to Dr. N. K. Panikkar, the Chief Research Officer of the Central Marine Fisheries Research Station, for going through the manuscript and suggesting improvements; to Mr. S. K. Banerjee, Statistician, for the help rendered in the presentation of numerical data; and to Mr. R. Jayaraman, the Biochemist, for the estimation of salinity values.

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7

STUDIES ON THE LIFE-HISTORY, BIONOMICS AND FISHERY OF THE WHITE SARDINE, *KOWALA COVAL* (CUV.)*

by

R. VELAPPAN NAIR**

ABSTRACT

An account is given of the breeding habits, egg, larval development, food, age and rate of growth, sexual maturity and sex composition, methods of fishing and fluctuations in the fishery of the white sardine, *Kowala coval*, a shoaling clupeoid fish of the West Coast of India.

The white sardine, *Kowala coval* (Cuv.), is one of the few economically important clupeoid fishes of the West Coast of India, the fisheries of which have assumed importance in recent years owing to the decline of the fishery of the valuable and much esteemed oil sardine, *Sardinella longiceps*. The highly fluctuating nature of the oil sardine fishery and its undependability, coupled with its failure during the last decade, are the main factors responsible for the present commercial exploitation, though on a moderate scale, of the fisheries of the white sardine and the other sardines, which were almost neglected in former years when the oil sardines occurred in plenty. It is not surprising, therefore, that very little attention has been paid in the past to the study of the biology and the fishery of the white sardine and practically no information is available on these subjects.

Devanesan and John (1941) gave a brief account of its food, sizes, maturity and spawning season with special emphasis on its gonads and eggs. Chidambaram and Venkataraman (1946) have published brief notes on the fishery, sizes, food and spawning season of this fish along with tabular statements of the natural history of certain other marine fishes of the Madras Presidency. Devanesan and Chidambaram (1948) have briefly dealt with the bionomics and economic importance of the white sardine in their popular account of the common food fishes of the Madras Presidency. Recently Mookerjee and Bhattacharya (1950) contributed some valuable information about the distribution of this species and its growth rate based on material collected from the Canning River where the availability of the white sardine has been observed to be restricted to the April–October period of the year.

MATERIAL AND METHODS

The study of the early life-history is based on live planktonic eggs collected from the bi-weekly surface plankton hauls made from the foreshore waters off West Hill with an organdie townet. The healthy living eggs were isolated from these collections and reared in clean sea water in the laboratory aquarium for the study of development. In spite of repeated attempts made during the course of the last three years, difficulty was experienced in rearing the larvae beyond yolk absorption. Consequently the early stages in the life-history alone are described here.

The size frequency studies are based on random samples of white sardines collected regularly during the course of the last three years. These samples were taken from the commercial catches made from the West Hill area and from the bi-weekly laboratory collections made from the foreshore waters off West Hill up to a depth of four fathoms. The laboratory catches as well as the commercial ones have been analysed irrespective of the gears employed for the purpose since it was thought that this would give a truer picture of the population of the white sardine of the West Hill region. However, mention may be made that the majority of the analysed catches were made with the boat seine and the gill net which constitute the important gears used along this coast for the capture of pelagic shoaling fishes. The length frequency data presented in the tables are based on total length measurements of almost all the specimens in the catches, and whenever they were heavy, random samples of 100 to 300 alone were measured. For the analysis of size frequencies, half centimetre groups have been employed in view of the small size of the white sardine (example : 9 cm size group includes specimens measuring from 9.0 to 9.4 cm in total length). Sex determination of most of these samples was carried out for the last two years.

For the study of the food, feeding habits and other aspects of the white sardine, selected representative

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** Central Marine Fisheries Research Station, Calicut.

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samples alone were examined. The results of the quantitative and qualitative analyses of the stomach contents made during the last three years are given in tabular form. For the purpose of these analyses a fourth of the stomach contents alone has been utilised. The numerical groupings followed in the table are purely arbitrary ; but it is hoped that this will serve to give an idea of the important seasonal changes in the dominant constituents of the food.

LIFE-HISTORY

Egg

In 1926, Delsman described two types of clupeoid eggs collected from near Batavia and a few stages in their development. He identified the smaller of the two with a diameter varying from 0.7 to 0.82 mm and with three to twenty small oil globules as that of *Dorosoma chacunda* and the larger with a diameter of about 1 mm and with six to twelve similar oil globules as that of *Dorosoma nasus*. In 1933 he pointed out that these identifications were not correct since he found the small egg to be very common north of Surabaya, where *Clupeoides lile* (*Kowala coval*) was a common fish in the fishermen's catches. He, therefore, suggested that the smaller type might belong to *Clupeoides lile* (*Kowala coval*) and ascribed the larger one to *Dorosoma chacunda*. Devanesan and John artificially fertilised eggs of the white sardine ; these eggs had a diameter of 0.8 mm and yellow oil globules varying in number from four to eight ; but the authors failed to trace the development.

The egg of the white sardine is the most abundant fish egg in the coastal waters of West Hill. It first appears by October and continues till February, but the November-January portion of the period is the best when it occurs in enormous numbers to constitute the bulk of the fish eggs in the plankton. The results of the study of the gonadial condition have also shown that the ovaries of most of the females become well-developed with mature eggs—a few of them translucent—by the month of October. Spawning females, with almost all the eggs in the transparent condition and provided with oil globules in the clear segmented yolk, have been collected from November onwards. By February the bulk of the adult females were spent and recovering. From the evidence provided by the abundant occurrence of the eggs in the plankton and by the changes in the gonadial condition at maturity it can be assumed with a fair amount of certainty that intensive spawning usually takes place from November to January. Maximum occurrence of eggs, sometimes in swarms, has been noted only in the six to eight fathom foreshore waters and their scarcity in the deeper offshore waters indicates that the white sardine is a coastal breeder with the relatively shallow inshore waters as their breeding grounds. Spawning usually takes place at midnight or in the early hours of the morning as judged from the stage of development of the embryos in the planktonic eggs.

The eggs are pelagic, transparent and perfectly spherical with the diameter varying in the living condition from 0.7 to 0.8 mm. The yolk is transparent and spherical and shows distinctly the vacuolation characteristic of clupeoid eggs. A fairly wide perivitelline space is present. Shining transparent spherical oil globules are present in the yolk mass and their number usually varies from six to eight. Extreme variations from three to twenty-seven have also been noted in exceptional cases. The oil globules show a tendency to crowd on the ventral periphery of the yolk mass.

Embryonic Development

Eggs collected at 4 a.m. show the blastodermal cap fully formed as a dome-shaped structure projecting somewhat above the spherical contour of the yolk mass (Fig. 1). The oil globules occupy the

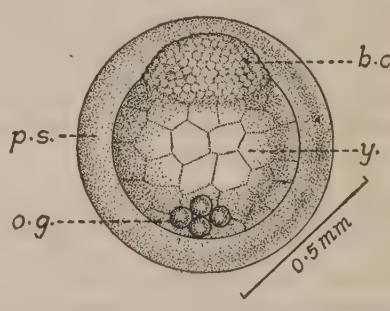

FIG. 1. Egg of *Kowala coval* at 4 a. m. b. c. : blastodermal cap ; p.s. : perivitelline space; o. g.: oil globule ; y.: yolk.

opposite side of the yolk mass where they are concentrated at one place in the peripheral region. With the advancement of the development of the embryo, the oil globules become scattered in the yolk mass.

Development is rapid and by 10 a.m. the embryo is well formed and occupies a little more than half the circumference of the yolk mass. The eyes, otocysts and the heart have formed, though the last is not yet functional (Fig. 2). The myotomes have also differentiated and about eighteen of them are present in the embryo in this stage. Unlike other clupeoid eggs, pigment is laid in the white sardine egg even in the early embryonic stage in a characteristic manner. Black unbranched chromatophores

have formed and these are scattered uniformly on the dorsal side of the developing embryo.

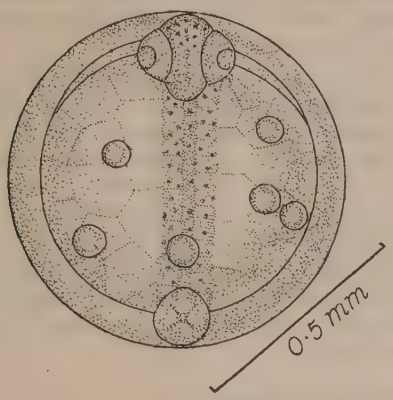

Fig. 2. Egg of *Kowala coval* at 10 a. m.

Embryonic development is usually completed by 2 p.m. when the egg is ready for hatching. At this stage the embryo occupies about three-fourths of the circumference of the yolk mass and performs frequent twitching movements inside the egg membrane with the aid of the caudal portion which is free from the yolk mass (Fig. 3). The full complement of myotomes is developed in this stage.

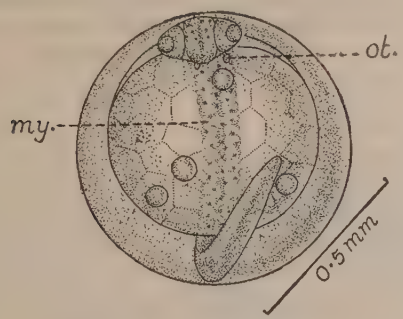

Fig. 3. Egg of *Kowala coval* at 2 p. m. ot. : otocyst; my. : myotome.

Hatching

The abundant occurrence of the eggs has made it possible to make a close study of the process of hatching which is rapid and takes only a very short time. The first sign of hatching is the slight, but quick, elongation of the spherical yolk mass along the embryonic axis to assume a cylindrical shape. The two rounded ends of the elongated yolk mass press against the egg membrane which becomes stretched, losing its spherical shape. The egg membrane splits open at the region of the head owing to the gentle pressure exerted by the elongated yolk mass. The opening thus formed is large enough for the head to be thrust out, but the aperture enlarges by the side to side twitching movement of the larva. The larva slips out quickly through this widened opening up to the caudal portion and by a few lashing movements of the tail rids itself of the shrivelled egg membrane. The process of hatching, as observed in the laboratory aquarium, is accomplished in a very short time, from one to two minutes. The duration is likely to be less under natural conditions of the sea where the process of hatching is accelerated by water movements.

Newly Hatched Larva

The newly hatched larvae are very inactive and float on the surface of the water upside down due to the buoyancy of the yolk and its oil globules. They measure 1.5 mm in length. The ellipsoidal yolk mass occupies about half the length of the larva (Fig. 4). The free caudal portion of the newly hatched larva is curved but becomes straight gradually in about an hour. The myotomes are distinct and about forty-two of them are seen in the newly hatched larva. The alimentary canal is long and straight and the vent which is situated far behind the yolk mass opens to the exterior below the thirty-fourth or the thirty-fifth myotome. The fin-fold is continuous and entire and originates dorsally from the anterior third of the larva. No change in the

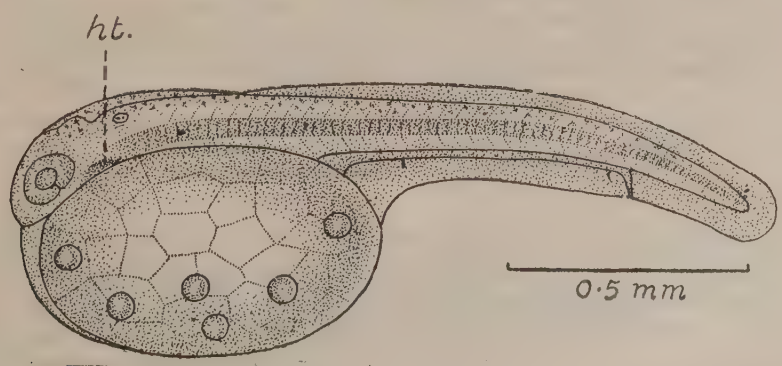

Fig. 4. Newly hatched larva of *Kowala coval*. ht. : heart.

pigmentation from that of the embryo is noticed, except an increase in the number of black chromatophores which are uniformly scattered over the entire dorsal side of the larva.

One Day Old Larva

The day old larvae are very active, the slightest disturbance making them dart from place to place. The usual stretching of the larvae has taken place and they measure 2.25 mm in length. The yolk mass is reduced in size considerably with the segmentation still seen distinctly (Fig. 5). The oil globules in the yolk mass have disappeared completely in some larvae while in others they have become very small. The auditory capsule has increased slightly in size. The pectoral fin has begun to develop and is seen in this stage as a small bud-like prominence above the yolk mass. The fin-fold has become wider and a slight anterior shifting of its origin has taken place. Indications of the formation of the caudal fin rays are seen in this stage.

Two Day Old Larva

These larvae are very active and swim at the bottom of the aquaria. They have grown in size and measure 3.1 mm in length. The yolk mass has disappeared in most of the larvae and its remnants alone are seen in some (Fig. 6). The mouth has formed and this synchronises with the disappearance of the yolk mass. The pectoral fin has grown into a transparent circular flap-like structure. The otocysts are larger. The caudal fin rays are clearly seen in this stage.

Marked changes have taken place in the pigmentation of the two day old larvae. All the unbranched black pigment cells seen scattered uniformly on the dorsal side of the embryo and in the previous larval stages have disappeared completely, leaving only a few ramifying ones in the interorbital region. New linear irregularly branching chromatophores of the same colour have appeared along the ventral side of the alimentary canal. The eyes also have assumed a bluish-green sheen with the pupils appearing dark in colour.

Three Day Old Larva

The larvae, which have become active swimmers on the third day, have been observed to frequent the bottom of the aquarium pecking at the sediments. They have increased in length and measure 3.5 mm. The pectoral fins have become larger in size (Fig. 7). The caudal fin rays have increased in number and are seen more prominently. A few more black, branching chromatophores have appeared in the vicinity of the heart and also along the base of the post-anal fin-fold. The eyes have become silvery-white in colour with deep black pupils.

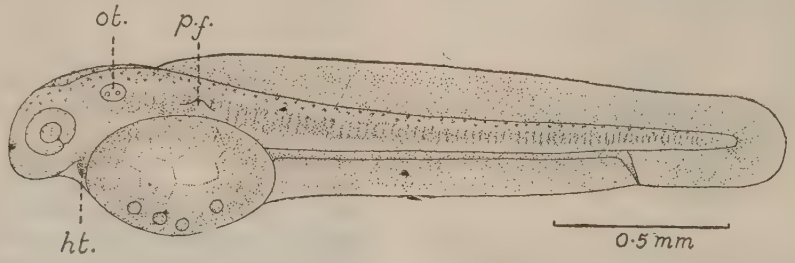

FIG. 5. One day old larva of *Kowala coval.* ot.: otocyst; p. f.: pectoral fin; ht.: heart.

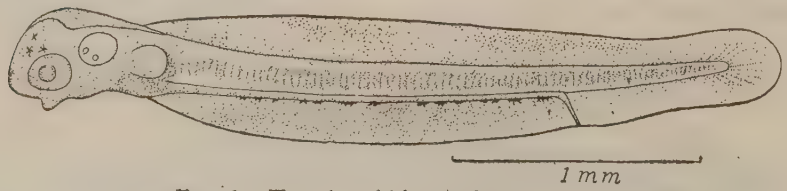

FIG. 6. Two day old larva of *Kowala coval.*

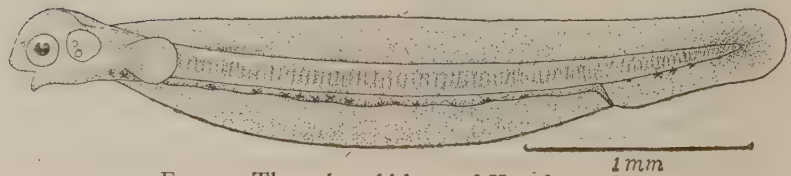

FIG. 7. Three day old larva of *Kowala coval.*

Four Day Old Larva

The larvae on the fourth day show no important changes except a slight increase in their length to 3.75 mm (Fig. 8). Most of the larvae in this stage have become inactive and emaciated in appearance, with the stomach region curved in, evidently due to lack of proper food. In this condition they are easily susceptible to attacks by the ciliates found in large numbers in sea water in spite of precautionary measures, causing a very high mortality. The few remaining ones become shrivelled up the next day, making it impossible to make any further observations. Many attempts were made to rear the larvae beyond this stage by providing them with carefully selected fresh plankton for food, but these proved futile and in all cases the larvae died during this critical transition period in their life-history.

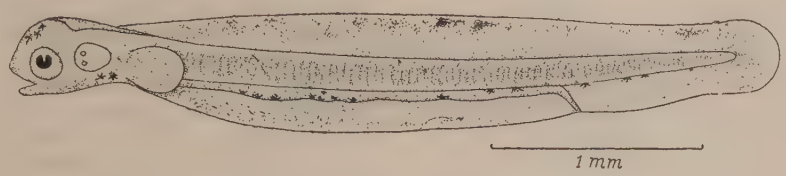

FIG. 8. Four day old larva of *Kowala coval*.

BIONOMICS

Distribution

The white sardine, *Kowala coval*, which is easily distinguished by its yellowish-white colour and silvery lateral band, is a widely-distributed species attaining a maximum size of 13 cm and is recorded from India, Pakistan, Ceylon, Burma, Malaya, Malay Archipelago and China (Misra, 1947). It is a shoaling species inhabiting the shallow coastal waters. Shoaling in vast numbers is known only from the West Coast of India. Recently Mookerjee and Bhattacharya have reported its occurrence in swarms even in the East Coast. Species of Leiognathus and Stolephorus have frequently been observed to occur in large numbers in association with the shoals of white sardine.

Food and Feeding Habits

The food of the white sardine consists exclusively of plankton. The results of the detailed quantitative and qualitative analyses carried out during the period of investigation have been briefly summarised in Table I in which among the different dominant organisms of the stomach contents, the maximum occurrence of each in a particular month alone has been given, following the arbitrary groupings indicated in the Table. It will suffice to give an idea of the relative seasonal abundance of the different generic constituents and their importance in the dietary of the fish. It is apparent that the most favoured food is the cladoceran, Evadne which, whenever it occurs in swarms in the foreshore waters, has been noticed to constitute the bulk of the food of this fish. This tendency to feed on Evadne is particularly pronounced in the young. Penaeid larvae, larvae of other crustaceans, Lucifer and the common copepods of the genera Acartia, Corycaeus, Temora, Oithona and Euterpina are the other important zooplanktonic forms contributing to their food. Occasionally fish eggs, mostly those of Caranx, have been observed in the stomach contents in fair numbers but no fish larvae have so far been observed. Of the phytoplanktonic elements, large numbers of Thallassiothrix (*T. frauenfeldii* and *T. longissima*) occasionally constitute the main food, but other genera like Nitzschia, Fragilaria, Coscinodiscus, Chaetoceros and Rhizosolenia have also been observed to contribute regularly to the food of the white sardine.

It has also been observed that intensive feeding takes place in the post-monsoon months, when there is rich production of plankton and this active feeding results in the accumulation of large quantities of fat with its characteristic sparkle in the abdominal cavity enveloping the viscera. This fat is utilised during the spawning period and no trace of it is seen in the spawners and spent white sardines.

Age Determination

The three methods usually employed for the age determination of fishes were adopted in this investigation. The scales and otoliths, particularly the latter, were subjected to intensive study by employing also the method adopted for the study of the otoliths of the oil sardine (Nair, 1949). Very early during the course of the investigation it became apparent that there is no indication of the presence of annual rings on these structures.

Therefore, Petersen's method alone was followed. During the three years of study 6,510 specimens belonging to 66 different samples were measured and analysed. The length frequency analyses for the years 1948, 1949, 1950 and for the entire period of investigation are given in Tables II, III, IV and V respectively. The length frequency polygons prepared separately for the three years and for the

entire period are given in Figs. 9 and 10. A study of these tables and figures shows the striking feature of the presence of only one mode represented by the 10.5 cm size-group which formed

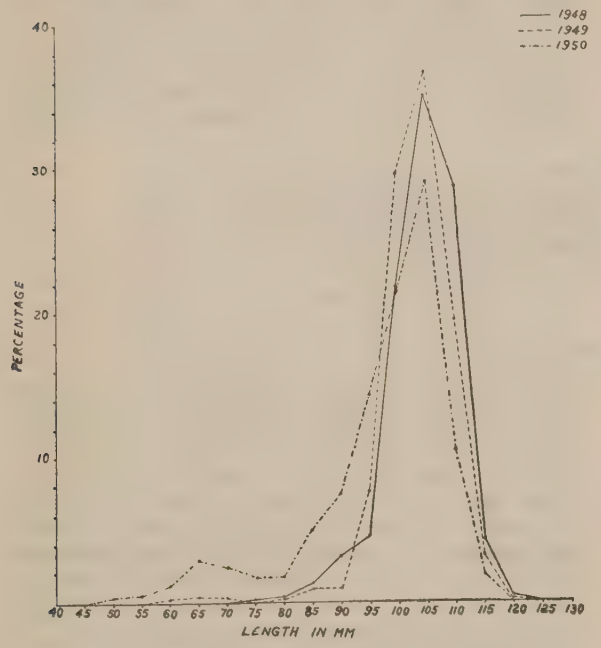

FIG. 9. The length frequency polygons of *Kowala coval* for the years 1948, 1949 and 1950.

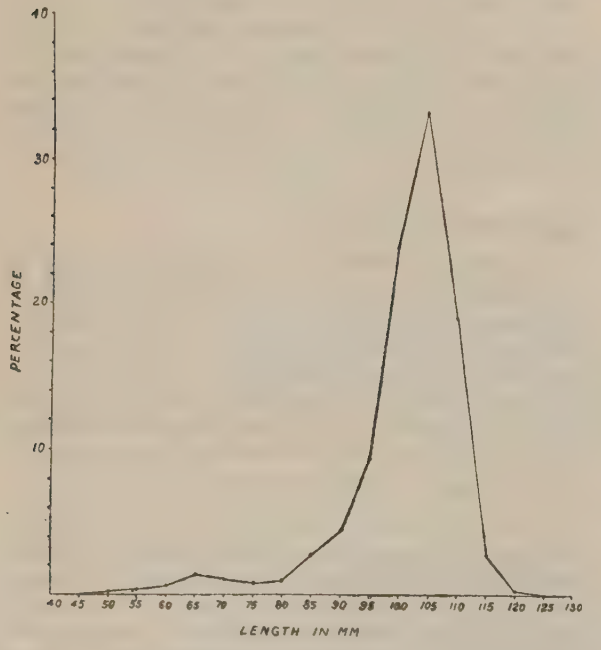

FIG. 10. The length frequency polygon of *Kowala coval* for the entire period of investigation (1948 to 1950).

about a third of the total measured during the period of investigation. The unimodal nature of the size frequency polygon clearly shows that there is only one age-group represented in the fishery. This year-class which dominates the fishery every successive year can only be the stock recruited during the previous spawning season. The rapid growth-rate is evident from the progressive increase in the proportion of the different size-groups up to the 6.5 cm group after which a slight fall in the next three groups is seen. This is mainly due to the seasonal fluctuations in the availability of the juveniles in the area under study. The smaller fish usually enter the fishery by May and a gradual increase in their number is seen up to August when the maximum number occurs in the fishing area. Their complete disappearance from the foreshore waters in the succeeding months is mainly due to certain environmental factors caused by the South West monsoon. The intensification of the monsoon in June and July results in the formation of ' mud banks ' in the foreshore areas when the sea water becomes heavily laden with fine mud which gradually settles down after the cessation of the monsoon. This is followed immediately by the occurrence of swarms of Noctiluca imparting a red colour to the sea water to constitute the ' red water phenomenon ' which is known to affect adversely the general fishery conditions. These factors particularly affect the post-larval and juvenile fishes which completely disappear from the foreshore waters during the August-October post-monsoon period. The repopulation of the area by these fish is gradual depending on the species. Though the white sardine fishery commences immediately after the monsoon, the juveniles take a much longer time to enter the foreshore waters. In spite of the fact that these factors have caused an insufficient representation of certain size-groups in the data, the absence of any other distinct mode to constitute another year-class leads to the inference that the average life span of the white sardine is about a year with only a relatively very small number surviving for a longer period as suggested by the sudden fall in the proportion of the higher size-groups. The new stock produced during the intensive spawning period extending from November to January apparently grows to a size of about 10 to 11 cms and dominates the best part of the white sardine season from September to November.

The results of the investigation on the white sardines of the East Coast done by Mookerjee and Bhattacharya for a restricted period of seven months give corraborative evidence in support of the conclusion arrived at by the Petersen's method of age determination. These authors have shown by a study of the younger stages obtained from the Can-

ning River where they migrate in shoals that the average length of the juvenile fish increases from 25.5 mm in April to 72 mm in October.

Sex Ratio

The sex composition of the random samples examined in 1949 and 1950 was determined and there were 1,392 males and 1,374 females with a negligible number constituting the indeterminates. The size frequency of the males and the females in 5 mm range of total length is given in Tables VI and VII and in Figure 11. Sex differentiation takes

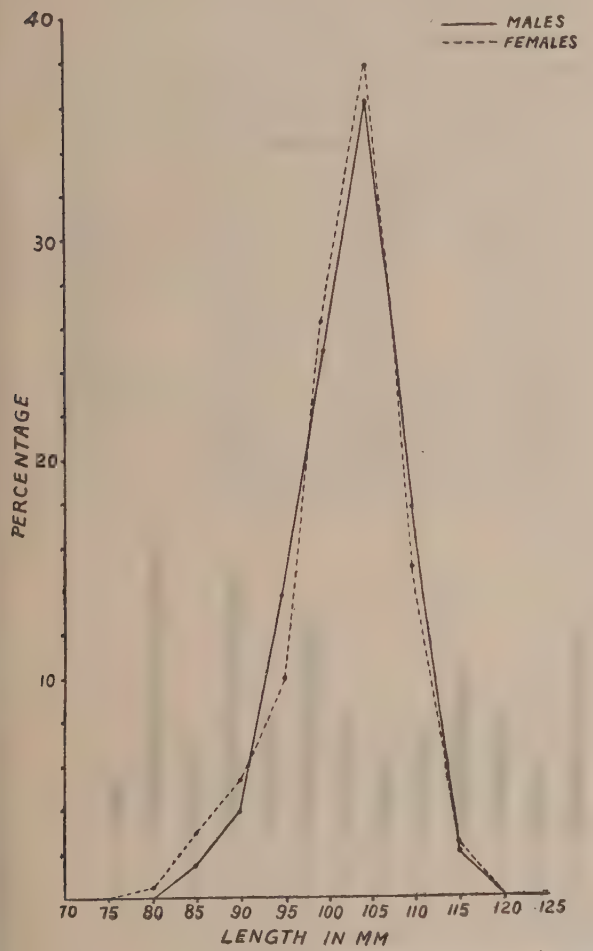

FIG. 11. The length frequency polygons of male and female *Kowala coval*.

place when the white sardines are small and the females become recognisable when they measure 7.5 cm while the males could be distinguished only when they measure 8 cm. It is also noticed that the females form a slightly higher percentage than the males in most of the size groups. The juveniles formed about 19 per cent of the total of each sex while the mature ones and spawners found within a narrow range between 10 and 10.9 cm constituted about 61 and 64 per cent of the total of males and females respectively. The higher groups were represented by about 20 per cent in the case of males whereas an appreciable fall to about 17 per cent was seen in regard to females. It is likely that this reduction in the number of females is caused by a higher rate of spawning mortality than in the males.

The complete atrophy of the right gonads is a characteristic feature of the white sardine. The left testis and ovary alone are functional and this is partly responsible for the very low fecundity. The estimated number of eggs in a mature female is about 8,000. Even though sex differentiation takes place at a very early size, the gonads attain full development only when the fish measure about 10 cm. In view of its short life span it is possible that each fish passes through the breeding season only once in its lifetime and the appearance of numerous small eggs in the ovaries of the spent and recovering individuals suggests the possibility of more than one spawning during the season.

Parasite

An unidentified cymothoan ectoparasite has been frequently noticed under the operculum of the white sardine.

FISHERY

The white sardine supports an important fishery along the West Coast, and the fishing season extends approximately from July to March. Very heavy catches, constituted mainly by fish ranging in length from 8 to 11 cm, frequently occur during the September to November portion of the season. The most important white sardine centres along the South Kanara and Malabar Coasts are :—Malpe, Kizhur, Puthiappa, Kadalundy, Parappanangadi, Tanur, Kootayi, Veliengode, Palapetty, Edakkazhiyur, Vadanapalli, Nattika, etc.

Fishing Methods

The white sardine fishery is confined to a narrow five to seven-mile strip of the coastal waters mainly due to the small size of the craft, namely the dugout canoe, commonly used by the fishermen along this Coast. The gear, however, has become efficient for the capture of these pelagic shoaling fishes during the course of several years. The most common nets used in the white sardine fishery are the gill net ' Chooda vala ' and the boat seine ' Paithu vala '. Other types of gill nets like ' Mathichala vala ' and boat seines like ' Nethal vala '

suited for the capture of oil sardine and whitebait are also used whenever the white sardine shoals are encountered unexpectedly while fishing for these shoaling fishes. The dimensions of the gill net 'Chooda vala' and the boat seine 'Paithu vala' are given below :—

Net	Length	Breadth	Size of mesh	Material
Gill net, 'Chooda vala'.	60′	10′	2/5″	Cotton
Boat seine, 'Paithu vala'.	Bag—40-45′ Platform—60′ Wings—160′	.. .. ..	1/5—1/2″ 8—9″ 3′	Cotton Coir Do.

The method of operation of these nets is similar to that of the gill nets and boat seines employed in the oil sardine fishery (Nair and Chidambaram, 1951). The boat seine 'Paithu vala' is usually employed during the peak of the fishery when large shoals frequently enter the coastal waters and immense catches are obtained with this net which, with its wings and platform, is ideally suited for the capture of the pelagic shoaling fishes. On the other hand the gill net 'Chooda vala' used exclusively for the capture of this fish, as the name implies, is used during the rest of the season for the capture of smaller shoals.

Fluctuations in the Fishery

The estimated total landings of white sardines from the fish-curing yards in the South Kanara and Malabar Coasts for the last 25 years are given below[1] :—

Table showing the estimated landings of white sardine in South Kanara and Malabar from 1925 to 1950

Seasons.	White sardines in Maunds. [2]	Seasons.	White sardines in Maunds.
1925-26	23,086	1938-39	9,783
1926-27	37,803	1939-40	15,873
1927-28	8,249	1940-41	21,826
1928-29	8,412	1941-42	14,421
1929-30	6,504	1942-43	9,789
1930-31	20,608	1943-44	15,286
1931-32	4,283	1944-45	27,981
1932-33	20,473	1945-46	15,617
1933-34	21,721	1946-47	33,488
1934-35	4,535	1947-48	10,836
1935-36	2,356	1948-49	36,845
1936-37	2,670	1949-50	6,263
1937-38	26,828		

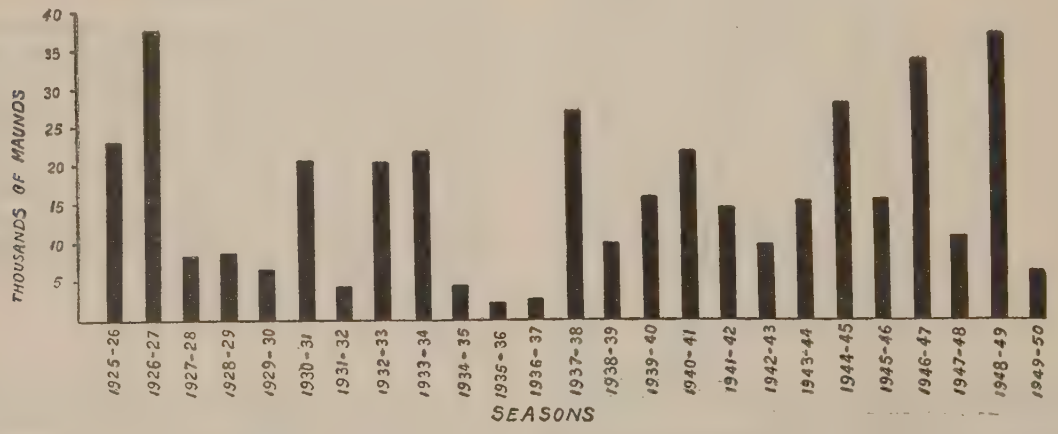

FIG. 12. The annual landings of *Kowala coval* in the South Kanara and Malabar Coasts from 1925 to 1950.

The fluctuating nature of the white sardine fishery is apparent from Fig. 12 prepared with the data given in the above table. The average annual landings for the entire period is about 16,000 maunds.[3] The landings of white sardine were more than 20,000 maunds in ten seasons. In some years the catches were relatively poor and the landings were less than 5,000 maunds in five seasons.

[1] I am grateful to Mr. K. Chidambaram for furnishing me with the data presented in the table.
[2] 27.22 Maunds = 1 Ton.
[3] The present value of a maund of white sardine is about Rs. 7.

Though the fishery varied from 37,803 maunds in 1926-27 to 2,356 maunds in 1935-36, an irregular fluctuation in abundance at intervals ranging from one to three years is seen. This is less when compared with the interval of two to six years in regard to the oil sardine. However, it is significant that both fisheries were good particularly in the years 1925-26, 1926-27, 1933-34, 1937-38 and 1940-41 after which the oil sardine fishery proved to be disastrous while the white sardine fishery showed a steady improvement in the years of abundance which is partly due to the increased exploitation consequent on the complete failure of the oil sardine fishery.

The white sardine is mostly consumed by the local people in the fresh condition and during the glut period the excess is usually cured with salt in proportions ranging from 8 : 1 to 10 : 1. It has very little economic importance on the East Coast because of its supposed non-availability in large numbers. But the recent findings of Mookerjee and Battacharya that it occurs in swarms on the East Coast also suggest the probable existence of an unexploited stock there.

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TABLE I

Analysis of the Food of White Sardine

Months	Rare (1-5)	Few (5-20)	Common (20-100)	Plenty (100-200)	Swarm (200 and above)
January	.. .. ..	Peridinium Prorocentrum Tintinnids Penilia Fish Eggs	Fragilaria Thallassiothrix Chaetoceros Polychaete Larvae	Oscillatoria	Evadne
February	..	Fragilaria Biddulphia Coscinodiscus	..	..	..
March	Biddulphia Fragilaria Coscinodiscus	Planktoniella	..	..	..
April	..	Coscinodiscus Ceratium Peridinium Copepods	..	..	..
May	Ceratium Larval Bivalves	Coscinodiscus Pleurosigma Biddulphia Ornithocercus	Polychaete Larvae	Copepods Crustacean Larvae	Evadne Penaeid Larvae
June	..	Rhizosolenia Coscinodiscus Prorocentrum Evadne Polychaete Larvae	Nitzschia Fragilaria	..	Thallassiothrix
July	..	Fragilaria Bacteriastrum Ceratium Tintinnids Copepods	Coscinodiscus Rhizosolenia Nitzschia	..	Evadne
August	.. ..	Asterionella Pleurosigma Oscillatoria Biddulphia Crustacean Larvae	Fragilaria Nitzschia Evadne Penilia Copepods Fish Eggs	Coscinodiscus Chaetoceros	..
September	Fragilaria Ceratium	Coscinodiscus Penilia Copepods Fish Eggs	..	..	Evadne
October	Planktoniella Prorocentrum	Biddulphia Evadne Copepods Fish Eggs	Nitzschia Lucifer	Coscinodiscus Fragilaria	..
November	Pyrophacus	Biddulphia Coscinodiscus Prorocentrum Penilia Copepods	Thallassiothrix Nitzschia Fragilaria Peridinium	Fish Eggs	Evadne
December	..	Rhizosolenia Copepods	Oscillatoria Fragilaria Coscinodiscus	Evadne	Thallassiothrix

TABLE II

Length Frequency Analysis for the Year, 1948

Months	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	Total
January	..	..	..	..	..	..	..	..	..	..	..	..	..
February	..	..	..	..	..	..	..	..	..	..	..	..	..
March	..	..	..	..	..	..	..	..	..	..	..	..	..
April	..	..	..	..	..	..	..	..	..	..	..	..	..
May	..	..	..	..	..	..	3	20	75	12	..	..	..	110
June	..	..	..	..	..	..	..	..	..	..	..	..	..	..
July	..	..	..	..	1	1	6	21	20	25	3	1	..	78
August	..	1	4	7	23	40	30	53	97	100	16	..	..	371
September	..	..	..	1	3	26	26	53	51	45	3	..	..	208
October	..	..	..	..	..	..	2	9	28	45	15	1	..	100
November	..	..	..	..	..	..	23	211	359	322	54	4	1	974
December	..	..	..	..	..	..	6	89	106	54	..	..	..	255
Total	..	1	4	8	27	67	96	456	736	603	91	6	1	2,096
Percentage	..	0.05	0.19	0.38	1.29	3.2	4.58	21.76	35.11	28.77	4.34	0.29	0.05	..

TABLE III

Length Frequency Analysis for the Year 1949

Months	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	Total
January	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
February	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
March	..	..	..	..	..	..	..	..	..	7	22	18	3	..	..	..	50
April	..	..	..	..	..	..	..	..	13	23	30	17	..	..	..	..	83
May	..	..	..	..	..	..	..	..	5	26	48	17	5	..	1	..	102
June	..	..	..	2	..	..	..	..	..	1	10	7	3	..	..	..	23
July	1	4	7	4	1	..	..	..	..	..	..	..	..	..	..	..	17
August	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
September	..	..	..	..	..	2	18	15	11	47	78	66	15	1	..	..	253
October	..	..	..	..	..	..	..	1	27	71	188	121	19	..	..	..	427
November	..	..	..	..	..	1	..	2	75	330	257	78	9	1	..	1	754
December	..	..	..	..	..	..	..	..	10	43	47	37	6	1	..	..	144
Total	1	4	7	6	1	3	18	18	141	548	680	361	60	3	1	1	1,853
Percentage	0.05	0.22	0.38	0.32	0.05	0.16	0.97	0.97	7.61	29.57	36.7	19.48	3.24	0.16	0.05	0.05	

TABLE IV

Length Frequency Analysis for the Year 1950

Months	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	Total
January	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
February	..	..	..	..	..	..	..	..	..	..	2	3	6	..	1	..	12
March	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
April	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
May	..	..	..	..	..	2	7	6	10	11	57	77	30	..	..	..	200
June	..	..	..	..	1	..	7	6	16	12	15	31	11	1	..	..	100
July	..	4	6	4	3	..	2	2	2	..	..	..	1	..	..	..	24
August	1	4	7	27	73	62	24	29	83	86	68	141	192	64	4	1	866
September	..	..	..	..	..	..	5	3	16	11	17	23	19	5	1	..	100
October	..	..	..	..	..	..	..	..	2	2	26	184	406	168	17	1	806
November	..	..	..	..	..	..	..	..	..	30	55	36	46	18	..	..	185
December	..	..	..	..	..	..	..	..	..	38	124	58	32	14	2	..	268
Total	1	8	13	31	77	64	45	46	129	190	364	553	743	270	25	2	2,561
Percentage	0.04	0.31	0.51	1.21	3.01	2.50	1.76	1.80	5.04	7.45	14.21	21.59	29.01	10.54	0.98	0.08	

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TABLE V

Length Frequency Analysis for the Years, 1948-50

Months	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	Total
January	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
February	..	..	..	..	..	..	..	..	..	..	2	3	6	..	1	..	..	..	12
March	..	..	..	..	..	..	..	..	..	..	..	7	22	18	3	..	..	..	50
April	..	..	..	..	..	..	..	..	..	..	13	23	30	17	..	..	..	..	83
May	..	..	..	..	..	2	7	6	10	11	65	123	153	29	5	..	1	..	412
June	..	..	..	..	1	2	7	6	16	12	15	32	21	8	3	..	..	..	123
July	..	4	7	8	10	4	3	2	3	1	6	21	21	25	3	1	..	..	119
August	1	4	7	27	73	63	28	36	106	126	98	194	289	164	20	1	..	..	1,237
September	..	..	..	..	..	..	5	6	37	52	54	123	148	116	19	1	..	..	561
October	..	..	..	..	..	..	..	..	2	3	55	264	622	334	51	2	..	..	1,333
November	..	..	..	..	..	..	..	1	..	32	153	577	662	418	63	5	1	1	1,913
December	..	..	..	..	..	..	..	..	..	38	140	190	185	105	8	1	..	..	667
Total	1	8	14	35	84	71	50	57	174	275	601	1,557	2,159	1,234	176	11	2	1	6,510
Percentage	0.02	0.12	0.22	0.54	1.29	1.09	0.77	0.88	2.67	4.22	9.22	23.92	33.16	18.96	2.70	0.17	0.03	0.02	

TABLE VI

Length Frequency Analysis of Males

Months	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	To tal
January	..	..	..	..	..	..	..	..	..	..	..
February	..	..	..	2	1	3	..	..	..	...	6
March	..	..	..	..	3	9	14	3	..	..	29
April	..	..	..	6	14	13	8	..	..	..	41
May	..	..	..	2	13	29	8	2	..	1	55
June	..	..	..	..	1	3	4	1	..	..	9
July	..	..	..	..	..	..	..	..	..	..	..
August	1	19	14	14	52	95	28	2	..	..	225
September	..	..	..	..	8	20	15	5	..	..	48
October	..	..	..	8	50	150	93	11	..	..	312
November	..	..	21	73	145	138	46	4	..	..	427
December	..	..	18	85	58	44	32	2	1	..	240
Total	1	19	53	190	345	504	248	30	1	1	1,392
Percentage	0.07	1.36	3.81	13.65	24.78	36.21	17.82	2.16	0.07	0.07	

TABLE VII

Length Frequency Analysis of Females

Months	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	Total
January	..	..	..	..	..	..	..	..	..	..	..
February	..	..	..	..	..	2	3	..	1	..	6
March	..	..	..	..	..	4	13	4	..	..	21
April	..	..	..	..	7	9	17	9	..	..	42
May	..	..	..	..	3	13	19	9	3	..	47
June	..	..	..	..	..	..	7	3	2	..	12
July	..	..	..	..	..	..	..	..	..	..	..
August	1	5	40	40	27	70	90	34	1	..	308
September	..	..	2	3	..	18	31	28	8	1	91
October	..	..	..	..	12	74	205	69	9	..	369
November	..	..	..	10	40	126	100	31	2	..	309
December	..	..	..	20	49	43	34	18	5	..	169
Total	1	5	42	73	138	359	519	205	31	1	1,374
Percentage	0.07	0.36	3.06	5.31	10.04	26.13	37.77	14.92	2.26	0.07	..

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PRELIMINARY REPORT ON AIR TRANSPORT OF LIVE FISH IN SEALED TINS UNDER OXYGEN PRESSURE

by

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ABSTRACT

Experiments on the transport of small fish in water jerry cans with oxygen introduced under pressure are reported. Role of CO_2 accumulation is noted as a limiting factor, and experiments in the use of buffers are reported. A formula relating average weight of fish, the time of the journey, and the number of fish to be carried, to a constant has been applied and a value determined for the constant for certain species, thus allowing accurate statement of the numbers of fish to be carried.

In transporting live fish or fry over short distances the Indonesian fisherman does not encounter great difficulties. The flat, coal-tarred baskets, carried on a bamboo pole slung over the shoulder, in which fish is kept alive in shallow water, are most suitable. Buschkiel (1937) gives good descriptions and illustrations of the various methods of transport.

However, when manpower is inadequate, as in the case of long-distance transport by road, rail or boat, there are quite a few difficulties. In such cases trained personnel must accompany the fish on the journey. Expenditure is high and success often doubtful. Transport by air in ordinary open baskets is practically impossible.

The following notes are in the nature of a preliminary report on certain experiments carried out at Bogor with the method of transport first described by the American Bureau of Fisheries in Document No. 1,045 and subsequently elaborated by Birtwistle (1931). Our thanks are due to Mr. Le Mare, Director of Fisheries, Singapore, and the Federation of Malaya who, in personal communications, drew our attention to this method.

In the investigation reported here, this method was tried out in the laboratory and in actual practice, and some improvements were worked out. During our work the article by Sundara Raj and Cornelius (1949) describing transport of carp was published. These authors used a somewhat more complicated vessel than ours, and cooled with ice.

METHOD USED

The principle of the method is to make the fish independent of oxygen diffusion from the air by providing this gas under pressure in closed tins. Birtwistle used ordinary petrol cans with a hermetically sealed screw-cap, and fitted with two small pipes for introducing the oxygen. Originally we used a similar tin, but as the tins are very thin we changed over to the army-type drinking-water jerry cans; these are extremely strong; the inside is coated with non-corroding paint; the lid is large and is hermetically closed with a snap-fastener. The only alteration necessary is to solder two pipes in the top next to the lid. These containers car be sent by air without any packing.

The procedure is as follows. Firstly, the tins must be nearly filled with clean, filtered pond water; rainwater is unsuitable because of its deficiency in lime, and tap water containing chlorine should be avoided. Natural, hard water is most suitable when passed through a filter to eliminate all living organisms able to consume oxygen and produce carbon dioxide in the dark. Secondly, the fish are introduced and the tin is completely filled with water, all air being excluded. Thirdly, one of the pipes is connected to an oxygen cylinder and gas is introduced. Birtwistle used a short pipe, but we prefer a pipe reaching almost to the bottom of the can and having a narrow aperture so that the oxygen can bubble through the water.

Since the can is quite full, water equal to the volume of oxygen introduced, is forced out through the second pipe. This volume is measured to check the correct amount of gas introduced. Both pipes should almost reach the bottom of the can so that no fish can pass beneath the sharp ends and be damaged. When the oxygen is introduced the fish usually swim about in great confusion and, in our first experiments, were observed to be hurt when touching the ends of the pipes. When the desired amount of oxygen has been introduced the pipes must be closed hermetically; we used ordinary vacuum tubing and a strong pincher. During transport the jerry can should be placed on its side so as to ensure the best contact between gas and water, and to facilitate diffusion.

PRACTICAL RESULTS

After successful preliminary experiments with cans and glass bottles, we were able to meet the demands from Fishery Officers outside Java, and the shipments made are mentioned in Table I.

TABLE 1

Species	Number	Total weight grams	Length cms	Destination	Approximate[1] time — hours	Percentage alive
Puntius javanicus (Blkr.) ..	+2000	unknown	1-1.5	Bandjermasin	23	+98
Puntius javanicus (Blkr.) ..	+2000	+460	2.5-3	Bandjermasin	23	+93
Cyprinus carpio L. ..	60	120	5			
Cyprinus carpio L. ..	4	180	15	Bangkok	48	100
Cyprinus carpio L. ..	6	670	20			
Osphronemus goramy Lac. ..	4	550	15-18	Cairo	50	100[2]
Tilapia mossambica Peters ..	4	244	18			
Tilapia mossambica Peters ..	135	200	2.25-4	Amboina	30	10[3]
Osphronemus goramy Lac. ..	200	320	2-3	Makassar	12	100
Cyprinus carpio L. ..	200	310	4-5	Bangkok	20	100
Tilapia mossambica Peters ..	200	600	5-6	Pontianak	24	100
Tilapia mossambica Peters ..	200	580	5-6	Balikpapan	244	100
Trichogaster pectoralis (Regan) ..	40	200	6-7	Samarinda	95[4]	32
Tilapia mossambica Peters ..	50	850	9-10	Pangkal Pinang	24	100
Trichogaster pectoralis (Regan) ..	50	110	4-6	Balikpapan	24	100
Trichogaster pectoralis (Regan) ..	70	128	4-6	Samarinda	24	90

The Table shows that the method was a success for inter-insular transport, with the exception of one case when the tin leaked. This failure made the change-over from the ordinary petrol cans to the jerry can a necessity after which no further leakage occurred. Although the method was intended for transport of fry or fingerlings, full-grown fish can also be shipped, as is illustrated by the transport to Cairo. After the usefulness of the method for fishery extension work in Indonesia had been proved, further research work was undertaken.

LABORATORY EXPERIMENTS

In order to gain an insight into the physiological processes involved we carried out some experiments in large 20-litre glass flasks, containing, 15 litres filtered pond-water and 5 litres oxygen, and connected throughout the experiment with an open manometer filled with mercury to measure the gas consumed.

Although identical amounts of water and oxygen were used conditions of oxygen diffusion were not absolutely identical in both cases because the cross-section of the two differs somewhat; it was nevertheless found that results obtained with the flasks could be reproduced with the cans. In Table 2 some results are summarized.

TABLE 2

Results of Laboratory experiments in 20-litre flasks with fish.

Species	Length cm	Total weight grams	Number	Time hours	Percentage alive
Puntius javanicus (Blkr.) ..	0.8-1	106.5	1778	47	99
do. ..	2.5-3	146	660	24	100
do. ..	1-1.5	138	3405	24	99
Cyprinus carpio L. ..	2-5	433	230	25.5	100
do. ..	3.5-8	120	30	28	100
do. ..	1.5-2	180	1000	42	93
do. ..	15-18	500	6	47	100
do. ..	20-21	780	6	50	100
Helostoma temmincki C.V. ..	2.5-3	400	400	21	93
do. ..	3.5-4.5	463	437	25	95
Osphronemus goramy Lac. ..	2	60	100	24	100
do. ..	2.5-4	66	98	13.5	97.5
do. ..	5-8	270	100	24	100
do. ..	23	550	3	50	100

Note: [1] Time between closing and opening of the can.
[2] Carp in one can, Guramy and Mudjair in another.
[3] Leaking can.
[4] The can was not opened until 71 hours after arrival. The journey was calculated to take 24 hours.

In these experiments the point at which 10 per cent of the fishes showed severe signs of distress in swimming and breathing was taken as an endpoint. In some cases a few animals did not survive on opening the flask ; for this reason the percentage of survivors is not always 100 per cent.

RELATION BETWEEN TIME AND TOTAL WEIGHT

In actual practice the most important question is how many fish per container can be shipped over a certain distance. As it was our aim to present the method in a form such that untrained personnel could use it without risk, the first question is whether or not a relation between the total weight of the fish and the time they are able to survive in the containers, can be established. Experiments similar to those described above were carried out to find such a relation. All observations were carried out by the same person to reduce the danger of personal error.

Results are shown in table 3.

TABLE 3

Relation between total amount and time.

Tilapia mossambica Peters of 6-7 cm length in 20-litre flasks with 5 litres oxygen.

Total weight grams	Number	Gas consumed cms mercury	Time hours	Total weight × Time
600	132	31	29.5	3894
500	103	29	36	3408
400	82	27.6	52	4264
200	50	27	84	3400
100	20	23.5	195	3900

pH		Alkalinity[1]		CO_2 mgr/1		O_2 mgr/1	
before	after	before	after	before	after	before	after
7.0	5.5	1.3	2.2	4.8	206.4	6.79	3.17
7.0	5.5	0.9	1.7	2.4	182.4	7.68	14.32
7.5	6.0	1.4	1.9	4.8	180.0	5.02	7.23
7.0	6.0	0.8	1.3	2.4	177.6	7.53	15.51
7.0	6.0	0.5	1.3	0.0	196.8	7.82	11.52

It is shown in the above Table that the product of the time space and the total weight is constant within the limits of experimental error, which limits are bound to be rather wide, as the endpoint cannot be ascertained with a great degree of accuracy.

CHEMICAL PROCESSES IN THE WATER DURING TRANSPORT

The process of respiration results in a consumption of dissolved oxygen with concomitant production of carbon dioxide.

As it is a well-known fact that fish may die when the oxygen content has become low, as well as when the CO_2 has become too high, it seemed to be of interest to investigate which of the two processes would be the factor determining the lifetime of the fish in the closed cans during transportation.

While much is known about the oxygen-and-carbon dioxide threshold of European and American fish, no data are available on Indonesian species. The following simple experiments were carried out with *Tilapia mossambica* Peters, *Osteochilus hasselti* (C.V.) and *Cyprinus carpio* L. Six fish weighing 2 grams each were placed in completely filled and stoppere Erlenmeyer flasks with filtered pondwater ; the oxygen and carbon dioxide content of the water before the experiment was measured and after successive half-hourly periods two Erlenmeyers in each section were opened and the oxygen and carbon dioxide determined.

The last determination was carried out when most fish showed severe signs of distress. This very simple method disregards individual differences between the fish and other precautions indicated in physiological literature, but might be adequate

Note : [1] By alkalinity we mean the amount of O/N HCL necessary for titration of 100 cc of the sample with methyl orange as an indicator.

to give an insight into the various amounts of both gases that can be tolerated by the species examined. Results are given in Fig. 1. We conclude that *Tilapia* has a higher rate of metabolism than both carps, that death occurs at a similar low level of oxygen pressure in all three cases and that carbon dioxide accumulates rapidly ; in the case of *Tilapia*

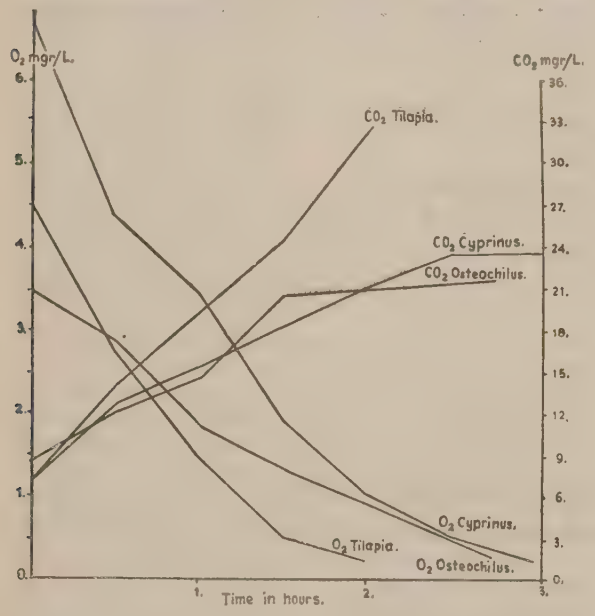

FIG. 1. Oxygen and carbon dioxide threshold for *Tilapia mossambica* Peters, *Cyprinus carpio* L. and *Osteochilus hasselti* (C. V.).

a higher value is reached sooner than in the case of the two carps. It does not follow from these experiments whether such an amount of CO_2 is lethal or not, as the level of the oxygen is so low at the end that respiration would have to cease for this reason alone.

If, at this stage, we return to the chemical data in table 3, we notice the following facts : (1) the pH drops, (2) the alkalinity increases, (3) the carbon dioxide increases enormously, (4) the oxygen is seen to increase in some cases as a result of diffusion from the gas atmosphere over the water, which gas, being pure oxygen instead of air containing only 21 per cent oxygen, will not be in equilibrium with the oxygen dissolved in water previously in equilibrium with the air. However, in cases where the amount of oxygen is lower at the end, the value is still far too high to cause death of the *Tilapia*.

The drop in pH is a consequence of the CO_2 production. The increase in alkalinity is caused by the production of faeces and slime by the fish. At the end of each experiment the water is found to be slightly turbid. Ivlev (1936) and others described this phenomenon. As a decrease in oxygen cannot be the cause of death the accumulation of CO_2 might well be regarded as such. In our experiments with Tilapia we found an indication for this in the outward appearance of the dead fishes. Death due to lack of oxygen is described by Plehn (1924) in the following words : " . . . . . tritt der Tod ein, so wird das Maul weit aufgerissen, die Kiemdeckel gehoben, und die Kiemen auseinander gespreitzt."

The author continues with the following words: " . . . . . Bei Kohlensaüre-Tod ist nur das Maul geöffnet, die Kiemen aber nicht gespreitzt ". Dead *Tilapia* always showed the phenomena described for accumulation of carbon dioxide.

EXPERIMENTS WITH BUFFERED SOLUTION

If the above hypothesis be valid, it should be possible to keep the fish longer in the cans when the accumulation of CO_2 is counteracted by a buffer. Only such buffer mixtures can be used that do not affect the fish, as boric acid was found to do. We added secondary sodium phosphate ($Na_2 HPO_4$) with marked results.

These experiments had to be carried out in sturdy vessels because, much to our surprise, the pressure created in the flasks by the consumption of gas by the fishes proved to increase to such an extent by the addition of the buffer that three Erlenmeyers used in earlier experiments cracked one after another.

Table 4 gives the results with *Tilapia*.

From the figures in this table the following conclusions can be drawn : (1) Buffering, even slightly, results in an increase in duration, since much more carbon dioxide can now be tolerated.

(2) For the above reason the fish are able to remain alive so much longer that the oxygen content of the water is much lower at the end.

(3) Thus accumulation of CO_2 rather than lack of oxygen seemed to limit the lifetime of the fish in the cans. For this reason we always added 5 litres oxygen only, without any extra pressure. To use more oxygen is obviously waste.

We wish to draw attention to the following :

It does not follow from a low value found for the oxygen dissolved in the water in a can at the end of an experiment that there is then no more oxygen available for the fish.

Actually the fish have reached this stage when their own oxygen consumption is higher than the supply by diffusion from the oxygen atmosphere above the water. The oxygen available in solution in the water has already been consumed, and the animals try to obtain more by using the top layer

TABLE 4

Influence of the addition of Na_2HPO_4 on survival of *Tilapia mossambica* in closed flasks filled with water and oxygen.

4.4-litre Erlenmeyers; oxygen 1.1 litre. Experiments discontinued when 10 per cent of the fish showed signs of distress.

30 Tilapia used in each case, length of fish 6-7 cms. Total weight 165 gm.

Na_2HPO_4 grams/litre	Consumption of gas cms mercury	Time hours	pH before	pH after	Alkalinity before	Alkalinity after	CO_2 mgr/1 before	CO_2 mgr/1 after	O_2 mgr/1 before	O_2 mgr/1 after
none	35	26.5	7.5	5.5	1.1	1.6	4.8	237.6	7.75	3.84
none	33.8	27	7.5	5.5	1.1	1.8	4.8	264	7.75	4.54
3	58	44	9.0	6.5	8.3	8.1	0	508.8	6.64	0.59
3	59.4	43	9.0	6.5	8.3	8.4	0	561.6	6.64	0.74
2	48.6	48	8.5	6.5	8.2	7.8	0	379.2	8.27	0.59
2	59.3	42	8.5	6.5	8.2	8.1	0	427.2	8.27	0.37
1.5	60.9	41.5	8.5	6.5	6.7	6.03	0	422.4	3.76	0.66
1.5	60.6	46	8.5	6.5	6.7	5.85	0	381.6	3.76	0.73

of the water in immediate contact with the gas atmosphere.

Diffusion into the water has decreased because of the constant consumption of oxygen and the fish will begin to suffer from lack of oxygen only when diffusion can no longer meet the demand. In the beginning the fish can be seen to swim about throughout the whole flask, but later on, when a vacuum is created in the bottle, all fish gather at the surface to utilize the oxygen-containing upper-layer. In this way they are able to subsist for a long time. Their reactions are somewhat slower. They are readily disturbed when the bottle is tapped but at a later stage they can hardly be frightened away from the surface. Eventually they lose their powers of equilibrium.

INFLUENCE OF THE LENGTH OF THE FISH

In studying the figures given in Table 2 it is evident that the individual length of the fish is most important. Big fish seem to hold out longer in the cans than small ones, even if the total amounts are equal. For practical purposes it is important to elucidate the influence of individual lengths of the material to be transported.

In Fig. 2 it is seen that respiration of small fish is relatively stronger than that of a similar weight of bigger ones.

This is a well-known relation in general physiology. The explanation is sought in the fact that, diffusion of oxygen and carbon dioxide through the total surface of the gills being the basic phenomenon of respiration, a value proportionate to the surface of the animal rather than to its weight will furnish a standard for its respiration. For warm-blooded animals Bergmann, Rubner and others long ago held the view that the intensity of respiration would be proportionate to the second power of the third root

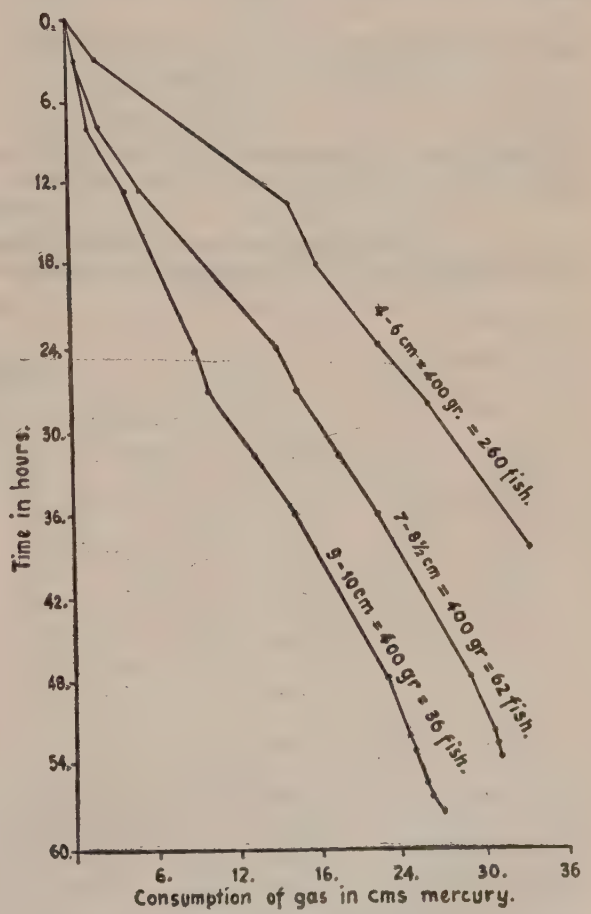

FIG. 2. Relation between duration and individual length (weight) in *Tilapia mossambica*.

of the weight. In the course of their investigations on metabolism of various fish of economic importance in Central Europe, German authors such as Zuntz, Knauthe, Cronheim and Lindstedt (vide Lindstedt, 1914) were able to give experimental proof of the validity of the same rule for carp, tench, pike and other fish, for oxygen consumption as well as for carbon dioxide production. They noticed considerable differences between the various kinds of fish. If the above relation holds in our case we can write it in the form of the formula: $N.W.^{\frac{2}{3}}T = C$ in which N = number of fish; W = average weight of one fish (in grams) and T = time (in hours). Since in actual practice the values for W and T are given, N can be calculated when the value for C has been established. The said factor C only applies for one set of conditions as regards the vessel used, the amounts of oxygen and water, etc. A strict uniformity in the length of the fish should be adhered to; and age, previous condition, etc. of all animals used should be exactly identical.

DETERMINATION OF THE FACTOR C FOR *TILAPIA MOSSAMBICA*

It has been our aim to establish the above factor C for all species of economic importance in Indonesia. We were obliged to carry out our experiments in flasks, since it was impossible to observe the fish sufficiently accurately in jerry cans and no reliable chemical determinations could be made in them. As stated above, results with flasks and jerry cans did not differ much.

Table 5 gives a summary of the experiments with Tilapia.

As shown in Table 5, we found the factor C to be constant within limits of an error of 3 per cent. For all practical purposes we should like to reduce the factor to 9,500 for periods of less than 100 hours and total weights below 1,000 grams and without buffering. When a buffer is applied, the number of fish can be increased by 40 per cent. When small fry are to be sent, great care must be taken not to use too delicate fish and notably not to weaken the fish by depriving them of food before transport, as is the usual practice.

It should be borne in mind that the method was not devised for transportation of large quantities but primarily to provide the extension worker with future spawners, in order to introduce the cultivation of a certain species into an area where it did not occur before. However, when economic conditions are favourable, large numbers of cans can also be sent, as in the transport of Chinese fish to Singapore at the moment, for which air freight is used on a fairly large scale.

TABLE 5

Relation between Number, Length and Time for *Tilapia mossambica*.

Number	Total weight grams	Length cms	Time hours	$C = N.W.^{2/3}T.$	
260	400	4–6	39	$260.\left(\frac{400}{260}\right)^{2/3}.39$	= 13480
62	400	7–8.5	53.5	$62.\left(\frac{400}{62}\right)^{2/3}.53.5$	= 11490
36	400	9–10	59	$36.\left(\frac{400}{36}\right)^{2/3}.36$	= 10580
13	400	15–16	86	$13.\left(\frac{400}{13}\right)^{2/3}.86$	= 10980
132	600	6–7	29.5	$132.\left(\frac{600}{132}\right)^{2/3}.29.5$	= 10685
103	500	6–7	36	$103.\left(\frac{500}{103}\right)^{2/3}.36$	= 10655
82	400	6–7	52	$82.\left(\frac{400}{82}\right)^{2/3}.52$	= 12500
50	200	6–7	84	$50.\left(\frac{200}{50}\right)^{2/3}.84$	= 10580
20	100	6–7	195	$20.\left(\frac{100}{20}\right)^{2/3}.195$	= 11404
100	300	5–6	50	$100.\left(\frac{300}{100}\right)^{2/3}.50$	= 12598
50	600	9–10	38	$50.\left(\frac{600}{50}\right)^{2/3}.38$	= 9958
				average ±	= 11355.5 · 325.09

EXPERIMENTS WITH COMMON CARP *CYPRINUS CARPIO*

Table 6 gives our results with the common carp, *Cyprinus carpio* in 20-litre flasks.

TABLE 6

***Cyprinus carpio* in 20-litre flasks (For headings of columns see table 3).**

N.	W.	L.	T.	pH b.	pH a.	Alkal. b.	Alkal. a.	CO_2 mgr./l. b.	CO_2 mgr./l. a.	O_2 mgr./l. b.	O_2 mgr./l. a.	$C = N.\ W.^{2/3} T.$
90	600	5-8	44	7.0	6.0	0.65	2.1	2.4	273.6	7.53	1.3	$90. \left(\frac{600}{90}\right)^{2/3} .44 = 14020$
50	300	5-8	83	7.0	6.0	0.7	1.8	2.0	268.8	7.50	1.47	$50. \left(\frac{300}{50}\right)^{2/3} .83 = 13702$
15	100	5-8	262	7.0	6.0	0.7	1.9	2.1	355.2	6.0	0.51	$15. \left(\frac{100}{15}\right)^{2/3} .262 = 13604$
195	400	4-6	44	7.5	6.0	1.0	2.3	0.5	345.6	7.68	0.44	$195. \left(\frac{400}{195}\right)^{2/3} .44 = 10997$ [1]
70	400	7-8	67	7.0	6.0	0.8	2.3	0.5	345.6	7.8	0.5	$70. \left(\frac{400}{70}\right)^{2/3} .67 = 14990$
26	400	9-10	110	7.0	6.0	0.7	2.6	1.0	374.2	6.0	0.22	$26. \left(\frac{400}{26}\right)^{2/3} .110 = 17690$ [2]
213	400	5-6	47.5	8.0	6.0	1.1	1.7	1.2	206.4	4.13	0.51	$213. \left(\frac{400}{213}\right)^{2/3} .47 = 15400$
												$= 14343.3$
												$\pm\ 771.43$

Here the experimental error is of the order of 5.5 per cent. The chemical data found in this case differ from those given in table 4.

The carp is able to tolerate higher concentrations of carbon dioxide and to use the available oxygen to a greater extent than Tilapia.

Experiments with phosphate-buffer in 4.4-litre Erlenmeyer flasks gave the following results.

TABLE 7

Influence of Phosphate-Buffer on *Cyprinus carpio*

No. 1. 35 fish of 6-7 cms length, total weight 150 grams.

Na_2HPO_4 mgr/l.	Time hours	pH before	pH after	Alkalinity before	Alkalinity after	CO_2 mgr/l. before	CO_2 mgr/l. after	O_2 mgr/l. before	O_2 mgr/l. after
none	36	7.5	6.0	0.9	1.9	0.4	292.8	5.17	0.51
1.5	49	9.0	6.0	4.4	4.9	0	530.4	4.60	0.14

No. 2. 32 fish of 6-7 cms length, total weight 150 grams.

none	28	7.0	5.5	0.9	1.7	4.8	278.4	6.79	0.88
1.5	50	8.5	6.0	4.4	4.9	0	506.4	5.91	0.14

It is seen in this table that the lifetime of the carp in the vessels is lengthened by the addition of the buffer, although they were able to utilize the available oxygen thoroughly even without phosphate. This can be explained by assuming that the acceleration of respiration by increased CO_2 pres-

Note: [1] The fish were in a weak condition before the experiment, for this reason the figure is somewhat low.
[2] The experiment was discontinued somewhat late, for this reason the figure is relatively high.

sure—a well-known fact in animal physiology—is reduced by the phosphate, and the rate of oxygen consumption is lower.

In an experiment carried out with the 20-litre flasks the results attained in the foregoing experiments were confirmed (Table 8).

TABLE 8

Influence of Na_2HPO_4—buffer on *Cyprinus carpio* in 20-litre flasks.

Na_2HPO_4 mgr/l.	Time hours	pH before	pH after	Alkalinity before	Alkalinity after	CO_2 mgr/l. before	CO_2 mgr/l. after	O_2 mgr/l. before	O_2 mgr/l. after
none	47.5	8.0	6.0	1.1	1.7	1.0	206.4	4.13	0.51
1.5	73	8.5	6.0	4.3	5.8	0	542.4	3.67	0.17

EXPERIMENTS WITH TAWES, *PUNTIUS JAVANICUS*

A series of experiments was carried out with *Puntius javanicus* (tawes) in the same way as those described above, without buffer. Results are given in table 9.

TABLE 9

Experiments with *Puntius javanicus*. (For headings of columns see table 3).

N.	W.	L.	T.	pH b.	pH a.	Alkal. b.	Alkal. a.	CO_2 b.	CO_2 a.	O_2 b.	O_2 a.	C.
33	500	9-10	56	7.5	6.0	1.1	2.3	7.2	343.2	5.61	1.03	11315
110	200	5-6	61	7.5	6.0	1.1	1.9	4.8	572	7.82	0.49	9988
148	300	5-6	40	7.5	5.0	1.1	1.9	4.8	321.6	7.82	1.18	9703
260	500	5-6	24	7.5	5.0	1.1	2.0	4.8	340.8	7.82	1.03	9649
250	500	5-6	21	7.5	5.5	0.8	1.9	7.2	283.2	9.15	0.88	8334
35	400	10-11	39	7.0	5.5	1.2	2.1	9.6	271.2	7.23	0.59	6925
80	400	7-8.5	39	7.0	5.5	1.2	2.1	9.6	312	7.23	0.59	9193
3405	138	1-1.5	24	7.0	6.2	0.65	1.2	..	..	..	..	9685
844	49	1-1.5	70	..	..	..	..	..	..	..	..	8858
										average ..		9294.4±403.9

It follows from the above table that in the case of Puntius a slightly smaller factor must be applied, namely 9,000. In all transportations a time safety margin should always be taken into account. In the case of small fry it is seen that over 3,000 fish lived for 24 hours in one container. Especially in the case of Puntius, the material to be transported should be examined carefully beforehand, because a few unhealthy individuals dying at an early stage are apt to spoil the whole can.

EXPERIMENTS WITH OTHER FISH

Experiments with other species are still in progress at this stage.

While not in a position yet to give figures for the factor C for *Osteochilus hasselti* (nilem), *Trichogaster pectoralis* (Sepat Siam) and *Helostoma temmincki* (tambakan), the results obtained so far are summarized in table 10.

TABLE 10

Preliminary results with various species
(For headings of columns see table 3).

N.	W.	L.	T.	pH b.	pH a.	Alkal. b.	Alkal. a.	CO_2 b.	CO_2 a.	O_2 b.	O_2 a.	C.
No. 1 : *Trichogaster pectoralis* **(Regan)** (*Sepat Siam*)												
270	385	3-4	34	7.0	6.0	0.7	2.4	10.4	624.0	4.87	0.88	11630
100	200	5-6	63	7.0	6.0	0.7	2.1	10.4	499.0	4.87	1.18	10000
No. 2 : *Osteochilus hasselti* (C.V.) (*nilem*)												
60	200	6-7	66	7.0	6.0	0.7	1.9	5.2	572.0	7.23	.49	8837
78	200	5-6	76	7.5	5.5	0.6	1.6	2.4	321.6	9.74	1.47	11107
27	200	8-9	102	7.5	5.2	0.6	1.8	2.4	374.4	9.74	2.06	10465
96	100	4-5	156	7.5	5.5	0.9	1.8	7.2	624.0	8.41	0.64	14570
377	400	4-5	29	7.5	6.0	0.9	1.8	7.2	436.8	8.41	0.55	11370
240	200	3-4	64	8.0	5.8	1.0	1.8	9.6	547.2	9.30	0.59	13600
No. 3 : *Helostoma temmincki* C. V. (*tambakan*)												
19	100	6-7	104	7.5	5.5	0.8	1.6	4.8	417.6	7.82	13.29	5979
79	400	6-7	23	7.0	5.5	0.8	1.8	7.2	628.8	7.08	12.11	5358
38	200	6-7	67	7.5	5.5	0.8	1.6	4.8	489.6	7.82	11.96	7703

We wish to add the following remarks to the above table. We do not regard experiments concerning either of the three species as conclusive, and we therefore have not calculated averages. We present the results obtained so far only as a confirmation of our data on the other species. In the case of the *Helostoma temmincki* we draw attention especially to the low value of the constant and to the high value of the oxygen at the end of the experiment. There is a striking difference between this and the other air-breather examined, the Trichogaster, for which no such low values were found. At this stage we do not comment on this phenomenon.

DISCUSSION

It follows from our formula N.W. $\frac{2}{3}$ T. = C. that big fish will hold out longer than smaller ones.

On the other hand, since the recipient of the consignment will wish to receive as many fish as possible, it will be preferable to use small fish. Apart from their relatively high oxygen consumption small fish have the disadvantage that they are delicate and easily hurt. Moreover, it is not advisable to withhold food from them before transportation because they soon weaken; as pointed out above, one or two fish dying at the beginning of a journey can spoil the whole can.

For this reason we warn against sending fish which are too small. The same rules as apply to ordinary transport should be observed. If we use our formula for working out a theoretical example we find that, if 800 fish weighing 1 gram each can be transported over a certain distance, 200 fish weighing 8 grams and 50 fish weighing 64 grams can be used. The total weights transported are, therefore, 800 grams, 1,600 grams, and 3,200 grams respectively. Thus we see that the most economical way of sending fish is to use the smallest possible size of material as long as there is no danger of mortality in transit owing to the delicate nature of the animals.

SUMMARY

The use of drinking-water jerry cans for air transport of fish and fry is described and the advantages over the tins used by Birtwistle discussed. Results obtained with this method in inter-insular transport in Indonesia are given in Table 1. In experiments, carried out in 20-litre flasks, where the fish were under constant observation and samples for chemical analysis could be taken it was found that, for fish

of the same length, there is an inverse relation between the total weight of fish flesh per flask and the time they can remain alive. It was found that CO_2 excretion is the principal factor limiting the life of *Tilapia mossambica* Peters in transport cans.

In many cases a considerable accumulation of CO_3 was found whilst the oxygen concentration at the moment of death of the animals was still far above the minimum which causes death : in simple experiments the oxygen threshold was found to be at a much lower level (Fig. 1).

In all cases the pH is seen to fall and the alkalinity is seen to increase as a result of excretion of slime and other metabolic waste products by the fishes. The position of the gills of the dying fishes also indicated carbon dioxide poisoning.

It proved to be possible to counteract the CO_2 accumulation by adding Na_2 HPO_4 to the water, to act as a buffer.

The survival period was markedly greater in the case of *Tilapi mossambica* and *Cyprinus carpio*. Tilapia was better able to utilize the available oxygen. Common carp proved to be able to utilize almost all the oxygen even when large quantities of CO_2 were present, and its lifetime in the closed containers was lengthened by addition of buffer. (Tables 4, 6, 7 and 8).

In studying the influence of individual length of the fishes it was found that the smaller the fish, the higher its metabolism (fig. 2). As a relation between the rate of metabolism and the individual weight raised to the power 2/3 was established in older German literature, it was thought that the formula : N.W. $\frac{2}{3}$ T = C might apply. Eleven experiments with Tilapia of different size, and with different numbers per flask are given in table 5. In these experiments the factor C was found to be constant, with an experimental error of 3 per cent. Using this factor under the same conditions as in our experiments the number which it is safe to send can easily be calculated when the duration of the transport has been estimated.

A similar factor was established for *Cyprinus carpio* L. (table 6) and *Puntius javanicus* (Blkr). (Table 9).

Experiments with *Trichogaster pectoralis* (Regan), *Osteochilus hasselti* (C.V.) and *Helostoma temmincki* C.V. have not yet been completed. Results attained so far are given in Table 10.

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9

THE ECONOMIC MARINE ALGAE OF MALAYSIA AND THEIR APPLICATIONS—II THE PHAEOPHYTA

by

J. S. Zaneveld*

ABSTRACT

A review is given of the Phaeophyta. This is the second of a series of papers of which the first dealt with the Cyanophyta and the Chlorophyta; the third paper, dealing with the Rhodophyta, will appear in this publication.

Whereas the first part of this series of papers on the Economic Marine Algae of Malaysia dealt with the Cyanophyta and the Chlorophyta, this second part contains a review of the applications of the Phaeophyta. As in the preceding paper (Zaneveld 1949) the genera and species are not arranged taxonomically, but alphabetically.

The classification of the brown seaweeds here enumerated is, in accordance with Fritsch (1945) as follows :—

Division	Order	Family	Genus
PHAEOPHYTA	Ectocarpales	Encoeliaceae	Chnoospora
	,,	,,	Hydroclathrus
	Dictyotales	Dictyotaceae	Dictyota
	,,	,,	Padina
	Fucales	Sargassaceae	Sargassum
	,,	,,	Turbinaria

The Rhodophyta will be treated in the third and last part of this series which will contain a full bibliographic list as well as an index to the Malaysian vernacular names.

Chnoospora J. G. Agardh

(*Order* : Ectocarpales. *Fam.* : Encoeliaceae.)

The members of this small genus of tropical (especially Pacific) algae are characterized by the irregular dichotomously branched thalli bearing numerous tufts of hairs, the forks being closer and closer upwards. The aggregated sporangia are spread over the surface and arise from the hairs.

The relatively tough, more or less compressed, wiry branches are composed of a central and a cortical tissue. The plants are in a dried state very dark brown. The tufted plants are attached to stones, rocks and pieces of dead coral in the littoral region.

Note : Though the under-mentioned species is only once recorded for the region under discussion (Java, cf. Levring, 1938) it is treated here, as it is difficult to distinguish from the nearly related *C. implexa* (Her.) J. Ag., which occurs in many parts of Malaysia. However, no mention is made about economic particulars of that species in Malaysia. The remarkable geographical distribution of *C. pacifica* may be an indication that the two species may be identical.

In the Hawaiian Islands the species is known by the vernacular names : limu wawahiwaa and limu kaupau (Reed, 1906).

Chnoospor pacifica J. G. Agardh.

Vernacular name : rau ngoai (Indo-China).

Literature : J. G. Agardh *in* Ofvers. Kongl. Vetensk.—Akad. Förh. (1847) 7 ;—Spec. Alg. (1848) 172 (sub nom. *Chnoospora fastigiata var. pacifica*).—Gruvel Rich. Mar. Fluv. Indo-Chine (1925) 137 (sub nom. *Chnoospora fastigiata*).—Burkill Ec. Prod. Mal. Pen. 1 (1935) 530.

Distribution : Indo-China ; Indonesia : Java; Atlantic Ocean : West Indies ; Indian Ocean : Durban, Ceylon ; Pacific Ocean : Japan, Australia, Hawaii Is., Coast of Mexico.

Use : The species is eaten raw, like a salad or relish, but nothing is recorded regarding its use in Malaya, the Philippines and Indonesia.

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Hydroclathrus Bory De Saint Vincent

(*Order*: Ectocarpales. *Fam.*: Encoeliaceae.)

The thallus of this very peculiar genus is in the full-grown state hemispherical and regularly pierced with orbicular holes. Growing older these holes gradually dilate more and more, thus forming an open mesh work up to 25 cm in diameter. The young thalli, in the earliest stages, are hollow and not perforated. On account of this, the mature specimens have the aspect of a sponge, which is loosely attached by the lower surface to the substratum.

Hundreds of these yellowish-olive netlike expansions are sometimes heaped together by wind and waves in the lagoons of the coral reefs. The colour, however, rapidly changes and the seaweeds become dark-brown in a dried state, whereas the plants lose rigidity at the same time.

Hydroclathrus clathratus (Bory ex C. A. Agardh) Howe.

Vernacular name : balbalulang (Philippines : Ilocos Prov.).

Literature : Bory De St Vincent in manuscript sub nom. *Fucus clathratus* (vide C. A. Agardh Sp. Alg. 1 (1823) 412, sub nom. *Encoelium clathratum*) ; Dict. Class. Hist. Nat. 8 (1826) 419 (sub nom. *Hydroclathrus cancellatus*).—Blanco in Fl. Filipp., ed. 1 (1837) 842 ; ed. 2 (1845) 582 ; ed. 3, 3 (1879) 262 (sub nom. *Ulva reticulata*).—Harvey Phycol. Austr. 2 (1859) pl. 98 (sub nom. *Hydroclathrus cancellatus*).—Von Martens Die Tange (1866) 47 (sub nom. *Encoelium clathratum*).—Merrill Sp. Blanc. (1918) 40 (sub nom. *Hydroclathrus cancellatus*).—Howe in Alg. Bahama Fl. (1920) 589.—Collado in Philipp. Agr. 15 (1926) 129 (sub nom. *Hydroclathrus cancellatus*).

Distribution : Malay Peninsula : Singapore; Philippines ; Indonesia : Borneo, Celebes, Java, Sumbawa, Timor, Tawi-Tawi Is., New Guinea. Seems to occur in all tropical seas and also in Australia.

Use : Collado (*op. cit.*) states that the species is eaten raw as a salad in the Philippines (Ilocos and Cagyan Prov.). However, Von Martens (*op. cit.*) did not believe that it was used by the natives there. Setchell (1905, p. 113) reports that Miss Tilden collected specimens of *Hydroclathrus clathratus* in the Hawaiian Islands under the native name " poha ", adding that : " It is eaten raw by the natives ", thus establishing the fact of the edibility of this species.

Dictyota Lamouroux

(*Order*: Dictyotales. *Fam.*: Dictyotaceae.)

The flattened thallus of these membranaceous plants arises from a stupose base. The branching exhibits practically a perfect dichotomy, the lobes being fan-shaped above with entire or dental edges. The thallus is composed of three layers, a central one of large colourless cells and an upper and lower cortical one of small cells with chromatophores.

The male and female sex organs are borne on separate plants. Both kinds of gametes are liberated in a single hour at about daybreak.

Asexual plants, showing a similar morphological appearance as the sexual ones, reproduce by means of tetraspores. All the reproductive cells derive from the superficial cell-layer.

When exposed to the sun, the olive-brown colour becomes verdigris green.

The plants occur on a rocky substratum in the lower belt of the littoral and especially in the sublittoral region.

Dictyota apiculata J. G. Agardh

Vernacular name : unknown.

Literature : J. G. Agardh Anal Algol. 1 (1880) 67.—Perrot and Gattin in Bull. Sci. Pharm. 18 (1911) 12.—Burkill Ec. Prod. Mal. Pen. 1 (1935) 805.

Distribution : Malay Peninsula; Indonesia : Celebes; Pacific Ocean : Australia, Tasmania.

Use : The plants are eaten where the surf throws them up on the beach, however, the present author does not know in what way.

In the Hawaiian Islands several other species of the genus Dictyota are eaten, among others, the widespread *Dictyota dichotoma*. Some of the species are bitter (Reed, 1907, p. 86).

Padina Adanson

(*Order*: Dictyotales. *Fam.*: Dictyotaceae.)

The thallus of the plants is flat, leafy, fan-shaped, fringed with articulated hairs, and marked at regular distances with concentric lines. The fronds are entire or sometimes split into sections. The tissue is differentiated into two kinds, a single upper and lower surface layer of assimilating cells, and a central one consisting of two or more layers of parallel-epipedal cells.

Male and female gametangia on the same plants, occurring in concentric zones between the fringed bands. The tetraspores are developed on separate plants of the same appearance and are scattered along the margins of the zones.

The property of the fronds of reflecting prismatic colours whilst growing under water, together with

the fan-like shape, have given the seaweeds the popular name of " Peacock's tail ".

The algae grow on a somewhat sandy bottom, in lagoons, etc., attached to little coral pieces, shells and stones by organs which are densely coated with woolly hairs. They occur in the lower part of the littoral (Zaneveld's semi-littoral belt, 1937, p. 466) and in the highest part of the sublittoral region.

Note : As it is not certain to what species Blanco's description applies, the most widespread one in the Philippines is mentioned below. *Padina distromatica* is only once recorded from Panay Island (Howe, 1932, p. 169).

Padina australis Hauck

Vernacular name : agar-agar daun besar (Indonesia : Klapa I.).

Literature : Hauck in Hedwigia (1887) 144.—Blanco in Fl. Filipp., ed. 1 (1837) 842 ; ed. 2 (1845) 581 ; ed. 3, 3 (1879) 261 (sub nom. *Ulva umbilicalis*). —Von Martens Die Tange (1866) 47 (sub nom. *Zonaria gymnospora*).—Merrill Spec. Blanc. (1918) 40.—Howe in J. Wash. Acad. Sci. 22 (1932) 170.—

Distribution : Philippines : Luzon, Panay Is ; Indonesia : Sumatra, Java, Celebes, Lombok, Sumbawa, Buru, Amboina, Djedan Is; Red Sea ; Pacific Ocean : China Sea, Australia.

Use : The species is sometimes eaten as a salad, but frequently it is collected for preparing a gelatine-like sweetmeat.

Sargassum C. A. Agardh

(*Order* : Fucales. *Fam.* : Sargassaceae.)

The plants belonging to this genus have the appearance of land plants showing a differentiation into " roots ", " stems " and " leaves ". The vertical dichotomously-branched axis is attached to the substratum by a distinct, often massive, lobed holdfast (the " roots "). The axis has a short stipe-like portion (the " stem "), and bears in the upper parts the repeatedly alternate branches on all sides with broad to filiform, entire or serrate leaf-like organs (the " leaves "), showing a mid-rib. Moreover it is often provided with stalked air-bladders (vesicles) and more or less forked, cylindrical receptacles, developing in the axils of the so-called " leaves ".

The stipes are attached to rocks, dead coral pieces, etc., in the sublittoral region, sometimes forming a dense zone around a coral island being settled upon the abrasion lay of the reef. On the other hand, masses of Sargassum plants are often seen floating in the sea having been torn off the shore by storms and carried to the open water by currents. The plants regenerate from broken thalli.

Note : The ash of burnt *Sargassum* species contains a large quantity of potash and carbonate of soda. Therefore the plants were cultivated in the coastal regions of some countries and the ash sold under the name of " kelp " (cf. Zaneveld, 1949).

Iodine is another valuable constituent found in the tissues, especially in those weeds collected in the open sea. Up to this time iodine industries exist in Japan and the U.S.A.

A chemical analysis of a *Sargassum* species carried out by Collado (1926, p. 134) in the Experiment Station Food Laboratory of the College of Agriculture gave the following result :

Moisture	33.44 %
Protein	5.01 %
Carbohydrates	30.24 %
Fat (ether extract)	1.29 %
Crude Fibre	5.13 %
Ash	24.89 %
Iodine	0.39 %

The species used, which is most probably *Sargassum siliquosum*, is known in Ilocos Province (Philippines) as " aragan ".

Sargassum is a very large genus of world-wide distribution. The Malays call them collectively "dandigum" (Burkill, 1935, p. 66). Mrs. Weber-Van Bosse (1928, p. 489) mentions for Indonesia alone 58 different species ! On account of this it is impossible to give the exact names of the species insufficiently described by the older authors like Rumphius and Blanco.

The *Sargassum* species cited in Blanco's Flora Filipinas (1837, p. 839 sub nom. *Fucus denticulatus* sp. nov. ; 1845, p. 579 and 1879, p. 259 ? sub. nom. *Fucus natans*) is, according to Merrill (1918, p. 46) : " apparently the one common at certain seasons in Manila Bay. Its true position within the genus Sargassum has not yet been determined ". Von Martens (1866, p. 45) adds to Blanco's species : " Verschiedene Arten von *Sargassum* ". The Philippine plants of this species are eaten by the natives ; however, neither Blanco nor von Martens were aware, in which way the food was prepared.

The *Sargassum* species mentioned by Vorderman (1895, p. 406) and by Hofstede (1923, p. 319) under the vernacular name " bebojot ", is eaten in East Lombok.

According to Hooper (1929, p. 28) the Chinese pharmacies in the Straits Settlements stock a dried

Sargassum species. The exact use is not known, but it is a recognized Chinese drug.

Sargassum aquifolium (Turner) C. A. Agardh

Vernacular names : ariën wari (Amboina) ; latak (Malay).

Literature : Turner Hist. Fuc. 1 (1808) 112, pl. 50 (sub nom. *Fucus aquifolius*).—C. A. Agardh Spec. Alg. 1 (1823) 12.—Rumphius Herb. Amb. 6 (1750) 186 (sub nom. *Agarum funiculare*, sive *foliatum* p. p.).—Von Martens Die Tange (1866) 43 (sub nom. *Carpacanthus herbaceus*).—Hasskarl Schlüssel Herb. Amb. (1866) 323 (sub nom. *Sargassum* sp.).—Merrill Interpr. Herb. Amb. (1917) 55.—Heyne Nutt. Pl. Nederl. Indië, 2nd ed., 1 (1927) 33.—Burkill Ec. Prod. Mal. Pen. 2 (1935) 1966.

Distribution : Indonesia: Sunda Str., Java, S. Flores, Timor, Amboina, Aru Is. ; Red Sea ; Indian Ocean: Nicobar Is. ; S. W. Pacific : Australia, New Ireland, Admiralty Is.

Use : According to Rumphius (*op. cit.*) the tops of the weeds are eaten raw or cooked with coconut milk.

Sargassum granuliferum C. A. Agardh

Vernacular names : ariën wari (Amboina); latak (Malay).

Literature : C. A. Agardh Spec. Alg. 1 (1823) 31.—Rumphius Herb. Amb. 6 (1750) 186 (sub nom.: *Agarum funiculare*, sive *foliatum* p.p.).—Von Martens Die Tange (1866) 43.—Merrill Interpr. Herb. Amb. (1917) 55.—Heyne Nutt. Pl. Nederl. Indië, 2nd ed., 1 (1927) 33.—Burkill Ec. Prod. Mal. Pen. 2 (1935) 1966.

Distribution : Malay Peninsula : Singapore ; Indonesia; Sumatra: Banka, Sunda Str., Java, Celebes, Timor, Amboina, New Guinea ; Indian Ocean; Pacific Ocean: China Sea, Japan, Australia, Tahiti Is.

Use : In Amboina the upper parts of the plants are eaten raw or cooked with either coconut milk or a little vinegar.

Sargassum polycystum C. A. Agardh

Vernacular names : agar-agar kupan (Moluccas) ; ariën hafulu, ariën malona (Amboina).

Literature : C. A. Agardh Syst. Alg. (1824) 304.—Burman Fil. Fl. Ind. (1768) 239 (sub nom. *Fucus natans*).—Rumphius Herb. Amb. 6 (1750) 185 (sub nom. *Acetabulum marinum*, sive *Agarum primum*).—Henschel Cl. Herb. Amb. (1833) 185 (sub nom. *Sargassum amboinicum*).—Hasskarl Schlüssel Herb. Amb. (1866) 181 (sub nom. *Sargassum myriocystum*).—Von Martens Die Tange (1866) 43 (sub nom. *Chauvinia macrophysa*).—Merrill Interpr. Herb. Amb. (1917) 55.—Heyne Nutt. Pl. Nederl. Indië, 2nd ed., 1 (1917) 33.

Distribution : Malay Peninsula : Singapore ; Philippines : Negros Is. ; Indonesia : Sumatra, Sunda Str., Java, Celebes, Bali, Sumbawa, Timor, Amboina, New Guinea ; Indian Ocean : Mauritius; Pacific Ocean: China Sea, Japan, Toud Is., Australia.

Use : According to Rumphius (*op. cit.*) the plants are eaten raw with lemon juice after being washed. Sometimes the seaweeds are first cooked with coconut milk. The natives in Amboina preserve the seaweeds smoke-dried.

Sargassum siliquosum J. G. Agardh

Vernacular name : aragan (Philippines : Ilocos Prov.).

Literature : J. G. Agardh Spec. Gen. Ord. Alg. 1 (1848) 316.—Seale in Philipp. J. Sci., D, 6 (1911) 309.—Wester in Dept. Agr. Nat. Res., Philipp. Is. Bull. 39 (1924) 21—Collado in Philipp. Agr. 15 (1926) 129.—Burkill Ec. Prod. Mal. Pen. 2 (1935) 1966.

Distribution : Malay Peninsula : Singapore ; Philippines : Luzon Is.; Negros Is ; Indonesia : Java Celebes, Kei Is., Aru Is., New Guinea ; Pacific, Ocean : China Sea, Japan, Australia, New Ireland.

Use : In the Philippines the seaweeds are eaten either fresh as a salad or cooked as a vegetable.

Turbinaria Lamouroux

(*Order* : Fucales. *Fam.* : Sargassaceae.)

The plants of this little genus are attached to the substratum by short-branched holdfasts, sending up one or a few simple or branched axes. The stiff cylindrical main axis or stipe bears the leaf-like organs. These have the appearance of a triangular shield or disk with a serrate or nearly entire margin, tapering downward usually in a pyramidal fashion to the petiole. The air-bladders, when present, are immersed in the leaf-like organs near the end. The receptacles grow into dense clusters from the base of the petioles.

The plants of this genus occur in the sublittoral region of the warm waters of the tropics and subtropics, growing on rocks and pieces of dead coral.

Turbinaria ornata (Turner) J. G. Agardh

Vernacular names : agar-agar lesong, sajur lompan (Malaysia) ; ariën essong, ariën hoar, arien makina (Amboina).

Literature : Turner Hist. Fuc. 1 (1808) 50, pl. 24 f (sub nom. *Fucus turbinatus* var. *ornatus*).—J. G. Agardh Spec. Gen. Ord. Alg. (1848) 266.—

Rumphius Herb. Amb. 6 (1750) 186 (sub nom. *Acetabulum marinum*, altera seu *infundibiliformis* species).—Henschel Cl. Herb. Amb. (1833) 185 (sub nom. *Sargassum turbinatum*).—Blanco in Fl. Filipp., ed. 1 (1837) 842; ed. 2 (1845) 581; ed. 3, 3 (1879) 260.—Hasskarl Schlüssel Herb. Amb. (1866) 181.—Von Martens Die Tange (1866) 43.—Merrill Interpr. Herb. Amb. (1917) 55.—Heyne Nutt. Pl. Nederl. Indië, 2nd ed., 1 (1927) 33.—Burkill Ec. Prod. Mal. Pen. 2 (1935) 2193.

Distribution : Malay Peninsula : Singapore; Philippines: Niuafoo Is ; Indonesia: Java, Postillon Is., Celebes, Madura, Sumbawa, Flores, Banda-Neira, Amboina, Buton Str.—in all tropical and temperate seas from Cape of Good Hope, New Zealand and Chile in the south to the China seas in the north.

Use : In the Moluccas the seaweeds are most frequently eaten raw with lemon-juice, however, sometimes they are cooked with coconut milk. Burkill (*op. cit.*) mentions that the seaweeds are made into a pickle in eastern Malaysia.

According to Setchell (1905, p. 100) the Kawaihae fishermen (Hawaiian Is.) report: " that limu-kala (which is the vernacular name applied equally to species of *Turbinaria* and *Sargassum*) is used for two purposes, viz. first for food; second, for getting atonement, religious, not moral. The one who has sinned gets all persons concerned together, makes prayer, and then throws the limu from him ".

In Malaysia, as far as the present author is aware, the seaweeds are not used in ceremonies of personal purification.

Turbinaria conoides (J. G. Agardh) Kuetzing

Vernacular name : labi--labi (Celebes).

Literature : J. G. Agardh Spec. Gen. Ord. Alg. (1848) 267 (sub nom. *Turbinaria vulgaris* var. *conoides*).—Kuetzing Tab. Phyc. 10 (1859) 24, pl. 66.—Rumphius Herb. Amb. 6 (1750) 186 (sub nom. *Acetabulum marinum*, species quae in Maccassarensium crescit litoribus).—Hasskarl Schlüssel Herb. Amb. (1866) 181 (sub nom. *Turbinaria vulgaris* var. *conoides*).—Von Martens Die Tange (1866) 43 (sub nom. *Chauvinia macrophya* ?).—Merrill Interpr. Herb. Amb. (1917) 56.—Heyne Nutt. Pl. Nederl. Indië, 2nd ed., 1 (1927) 33.—Burkill Ec. Prod. Mal. Pen. 2 (1935) 2193.

Distribution : Malay Peninsula : Singapore ; Philippines : Panay Is.; Indonesia : Sumatra, Java, Postillon Is., Celebes, Talaud Is., Flores, Amboina, Aru Is., New Guinea ; Red Sea ; Indian Ocean : Malabar coast, Ceylon ; Pacific Ocean : China Sea, Torres Str., W. Australia.

Use : According to Rumphius (*op. cit.*) the seaweeds belonging to this species are eaten raw by the native chiefs (Radja's) as a salad with a little vinegar. They are very pleasant in taste. Burkill (*op. cit.*) reports that these seaweeds are made into a pickle in eastern Malaysia.

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LES ESPÈCES DU GENRE SCYLLA À NHATRANG (VIETNAM)

by

R. Serene*

ABSTRACT

The species of Scylla found in Vietnam have been studied in relation to the systematic revision made by Estampador, and to establish the distinctive morphological characters of the species. The status of four forms is discussed : *Scylla oceanica*, *Sc. tranquebarica*, *Sc. serrata*, and *Sc. serrata* var. *paramamosain*.

LES ESPECES DE SCYLLA

Les carcinologistes ne reconnaissent d'ordinaire dans ce genre qu'une seule espèce. Miers (1886) ne reconnait que *Scylla serrata* ; Stimpson (1907) pense que *Scylla serrata* et *Scylla tranquebarica* sont synonymes. Dana (1852) et Stimpson (1907) ne donnent *Scylla oceanica* que comme une variété de *Scylla tranquebarica*. Estampador (1949) propose une revision taxonomique du genre *Scylla*, dans lequel il distingue trois espèces et une nouvelle variété ; il donne une clé de détermination. Il indique pour chacune de ses espèces un certain nombre de références aux synonymes des auteurs et je m'en remets à son travail à ce sujet. Une revision complète des synonymes de *Sc. serrata* entrainerait un travail considérable pour un résultat assez faible ; j'ai relevé plus de 80 références d'auteurs pour cette espèce.

Estampador (1940) fonde sa distinction des espèces et variétés sur des caractères les uns morphologiques, les autres tirés de l'oogénèse et de la

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spermatogénèse et sur les observations des pêcheurs Philippins ; ces derniers reconnaissent parmi les *Scylla* deux catégories :

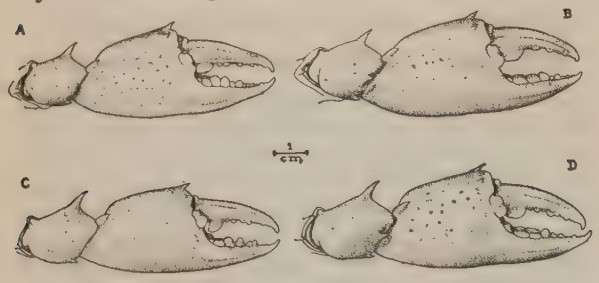

Fig. 1 : Pinces

Scylla oceanica ♂ de 62 mm (E. 18·038)
Scylla tranquebarica ♂ de 63 mm (E. 18·158)
Scylla serrata ♂ de 63 mm (E. 17·970)
Scylla serrata var. *paramamosain* ♂ de 64 mm (E. 17·974)

(Grandeur naturelle)

1°—*Les Banhawin* (nom donné dans la province de Quezon aux crabes, *bulika*, c'est à dire présentant des taches bigarrées) caractérisés par : a) des taches polygonales gris branchâtres bordés d'une ligne rouge ou brune ; taches nettes sur les jeunes et devenant indistinctes chez les vieux. b) une couleur verdâtre.

2°—*Les Mamosain*, caractérisés par : a) l'absence de taches bigarrées ou par seulement des traces de ces taches sur les dernières pattes. b) un couleur brun rouille à brun noir.

Les *Banhawin* correspondent aux deux espèces *Scylla oceanica* et *Scylla tranquebarica*. Cette dernière étant un *parabanhawin* et la première un *banhawin* vrai. Les *mamosain* correspondent aux espèces *Scylla serrata* et *Scylla serrata* var. *paramamosain :* la première étant un *mamosain* vrai. Les *Banhawin* auraient une vie nomade, les *mamosain* seuls creusant des terriers (trous d'habitation) d'où le nom d' " *alimango sa butas* " (crabes des cavernes) qu'on leur donne dans la province de Batangas.

LES SCYLLA DU VIETNAM

J'ai étudié les espèces de *Scylla* du Vietnam en fonction de la revision systématique d'Estampador (1949), et en précisant les caractères morphologiques distinctifs des espèces ; m'efforcant surtout de continuer le travail d'Estampador. Les Vietnamiens reconnaissent quatre catégories de crabes appartenant au genre *Scylla* qui toutes, selon les vues habituelles des carcinologistes, sont à rapporter à *Scylla serrata :*

1°—*Con cua chuôi* (littéralement crabe banane) encore appelé *con cua trang* (littéralement crabe blanc).

2°—*Con cua sen* (littéralement crabe vert).

3°—*Con cua lua* (littéralement crabe feu-rouge).

4°—*Con cua lan* (littéralement crabe roulant).

A l'état frais un examen attentif de la teinte générale et des couleurs de la carapace et des chelipèdes suffit en comparant de nombreux specimens pour séparer les deux catégories : *con cua chuôi* (crabe banane) et *con cua sen* (crabe vert) d'une part ; et *Con cua lua* (crabe feu) et *con cua lan* (crabe roulant) d'autre part.

En particulier la teinte vert clair de la face dorsale de la carapace et des chelipèdes et celle jaune tacheté de points bruns (comme une banane très mûr) de la face ventrale de la main des chelipèdes du *con cua chuôi* tranche nettement sur la couleur vert brun foncè, les chelipèdes bruns rouges du *con cua lua* (crabe feu). Je rapporte le premier à *Scylla oceanica* et le second à *Scylla serrata s.s.* c'est à dire au *Banhawin* et au *Mamosain* des Philippins. Les deux autres formes correspondent aux formes intermédiaires d'Estampador : *Parabanhawin* et *paramamosain* ; elles se distinguent moins facilement entre elles comme de chacune des formes dont elles sont voisines. Je rapporte les quatre catégories de *Scylla* des Pêcheurs Vietnamiens aux quatre espèces d'Estampador de la manière suivante :

— E. 18.038 : *Con cua chuôi* = *Scylla oceanica* Banhawin

— E. 18.158 : *Con cua sen* = *Scylla tranquebarica* parabanhawin

— E. 17.970 : *Con cua lua* = *Scylla serrata* mamosain

— E. 17.974 : *Con cua lan* = *Scylla serrata* var. *paramamosain* paramamosain.

Les N°s d'échantillons que je donne sont ceux des quatre specimens types, auxquels je me rapporte le plus souvent dans cette étude, et qui sont conservés dans les collections de l'Institut Oceanographique. Les quatre formes sont si voisines qu'on comprend sans peine que leur distinction ait échappé aux auteurs. Leur différenciation morphologique difficile semble indiquer que pour deux formes au moins le rang de variété doit être préféré à celui d'espèce ; la séparation des quatre formes en deux groupes de deux, l'un avec *Sc. oceanica* pour type et l'autre avec *Sc. serrata* s'imposant seule nettement. L'ancien *Sc. serrata* des auteurs se diviserait donc en deux espèces avec chacune une variété : *Scylla oceanica* avec *Scylla tranquebarica* comme variété et *Scylla serrata* avec *Scylla serrata* var. *paramamosain.* Ces réserves faites, pour ne pas compliquer les questions de nomenclature et compte tenu de l'état encore rudimentaire des résultats de

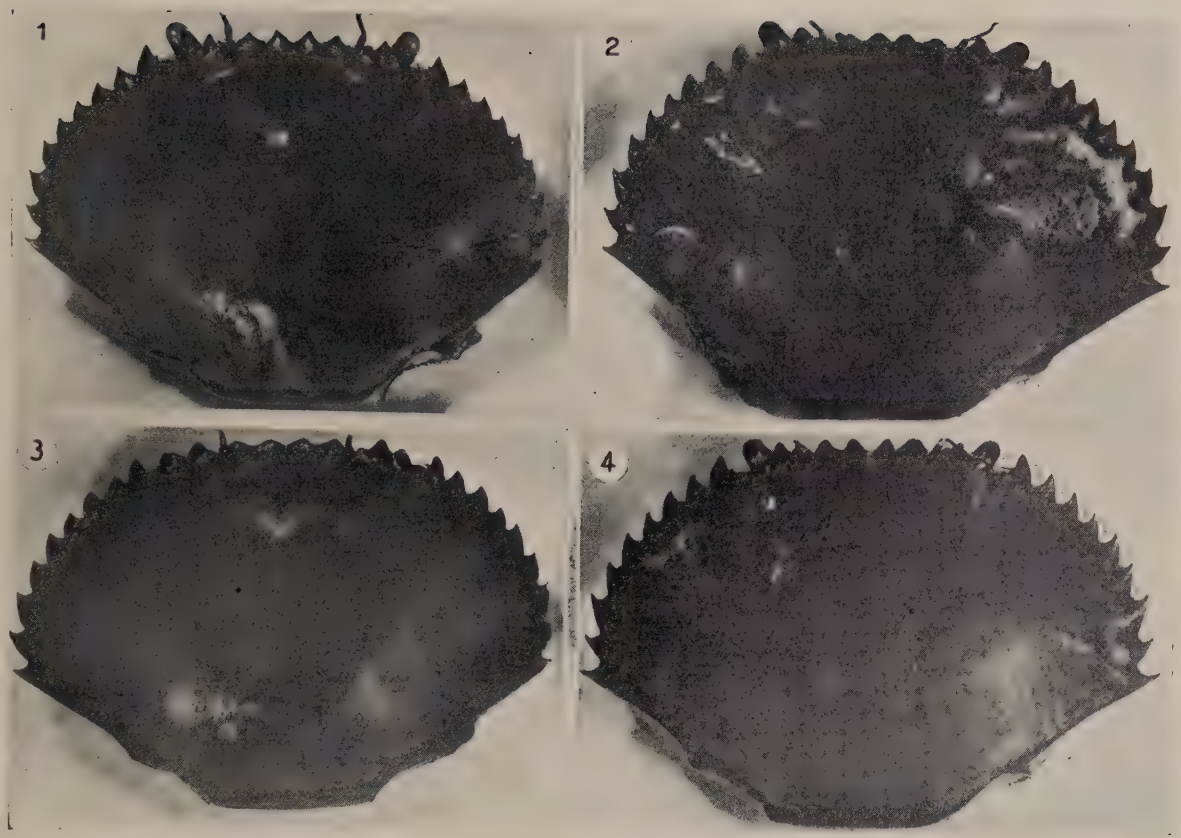

Plate I.—*Carapaces*

1.—*Scylla oceanica* ♂ de 62 mm (E. 18.038)
2.—*Scylla tranquebarica* ♂ de 63 mm (E. 18.158)
3.—*Scylla serrata* ♂ de 63 mm (E. 17.970)
4.—*Scylla serrata* var. *paramamosain* ♂ de 64 mm (E. 17.974)
—(Grandeur naturelle)—

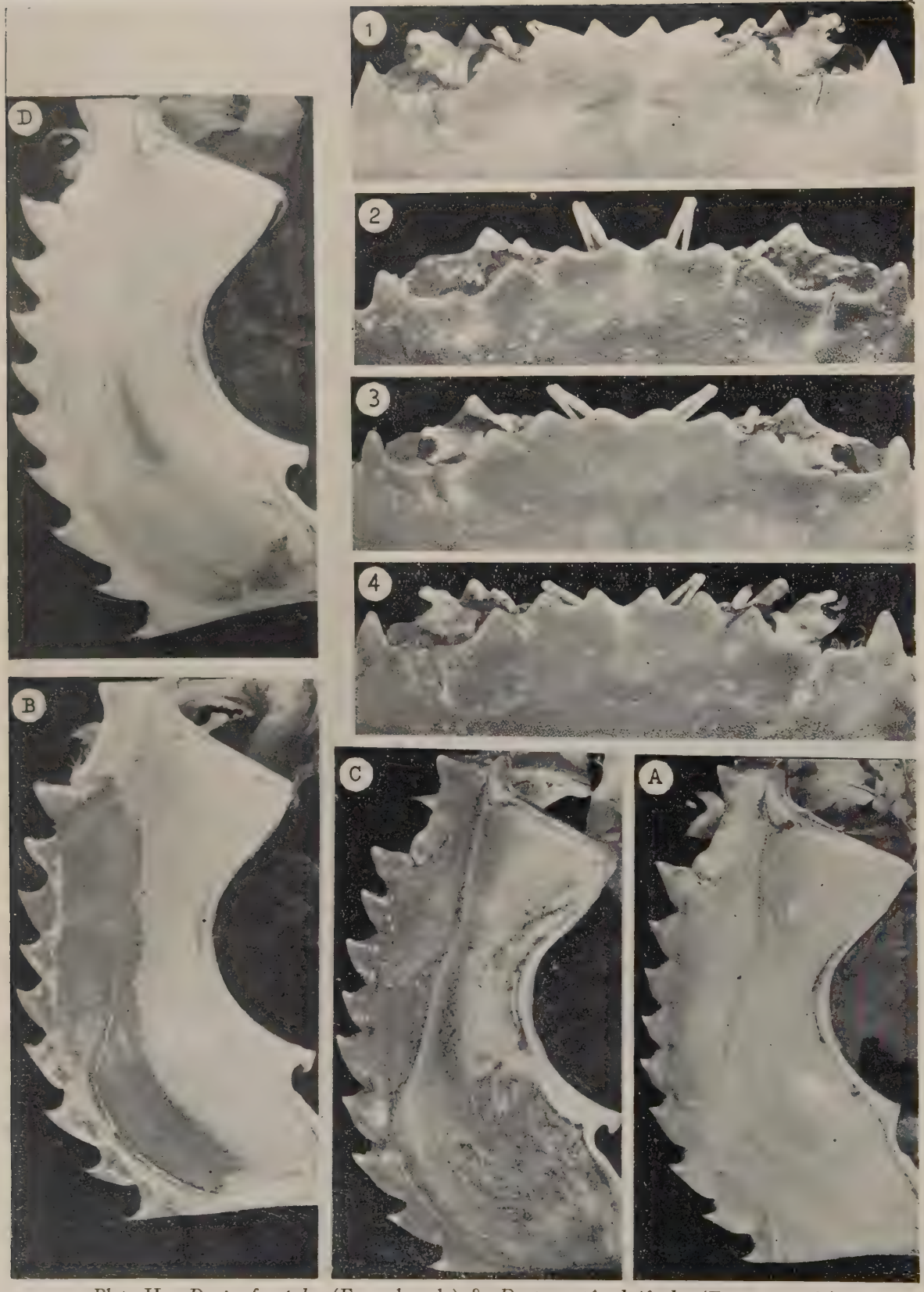

Plate II.—*Dents frontales* (Face dorsale) & *Dents antéro-latérales* (Face ventrale)

1	&	A.—*Scylla oceanica*	♀♀	de	62	mm	(E. 18.038)
2	&	B.—*Scylla tranquebarica*	♀♀	de	63	mm	(E. 18.158)
3	&	C.—*Scylla serrata*	♀♀	de	63	mm	(E. 17.970)
4	&	D.—*Scylla serrata* var. *paramamosain*	♂	de	64	mm	(E. 17.974)

—(Grossissement × 2)—

mes propres recherches, j'adopte la nomenclature d'Estampador.

L'etude des spécimens du Vietnam rapportés à ces espèces si elle précise plusieurs caractères morphologiques donnés par Estampador, confirme la valeur de certains et j'en ajoute d'autres; je ne crois pas possible toutefois pour le moment de modifier sa clé de détermination.

Les caractères distinctifs de coloration, puis ceux purement morphologiques seront examinés successivement dans les trois espèces et variétes.

COLORATION

Sc. oceanica et *Sc, tranquebarica* sont caractérisés d'après Estampador par une carapace à couleur générale verdâtre et *Sc. serrata* et sa variété *paramamosain* par une carapace à couleur générale brune ou brun verdâtre.

A l'état frais dans les specimens du Vietnam; *Sc. oceanica* est vert pâle, et *Sc. serrata* est brun foncé (brun ferrugineux d'Estampador) ou vert bleu de prusse foncé; ce qui concorde avec les observations d'Estampador. Ce sont les deux seules espèces qu'il est possible de distinguer à l'état frais par la couleur de la carapace. *Sc. tranquebarica* d'après Estampador est de teinte vert gris pourpre variant du sombre au brillant. Les specimens du Vietnam sont vert sombre avec des teintes pourpres, voire violettes. Comme indiqué par Estampador seule les pattes vertes sont nettement caractéristiques du groupe à teinte générale verte. A noter que le nom Vietnamien *Con cua sen* (*sen* veut dire *vert*) indique bien la couleur de cette espéce. Le *Sc. serrata* var. *paramamosain* est brun verdâtre. Je précise que dans les deux espèces *Sc. oceanica* et *Sc. tranquebarica*, le dernier article de la dernière paire de pattes est vert tandis que dans *Sc. serrata* et sa varieté ce dernier article est brun. Les variations de milieu de vie (lieu de récolte), et de taille (avec l'âge toutes les teintes deviennent plus foncées) des specimens s'accompagnent de notables variations des couleurs.

Les seuls caractères de coloration ne permettent guère de distinguer à l'état frais que les espèces *Sc. oceanica* et *Sc. serrata*, les indications complémentaires de coloration ci-dessous sont données d'après des spécimens déterminées en se basant seulement sur leurs caractères morphologiques.

Sur les carapaces séchées, la face dorsale de *Sc. oceanica* est jaune verdâtre, celle de *Sc. tranquebarica* est brun violet, celle de *Sc. serrata* vert brun olive avec des taches rousses en particulier deux grandes sur les regions peribranchiales postérieures de part et d'autre de la region cardiaque, celle de *Sc. serrata* var. *paramamosain* vert pâle avec des reflets mauve pâle. Sur la face ventrale, les bords antéro-latéraux sont jaune pâle dans *Sc. oceanica* et *Sc. serrata* var. *paramamosain* ; ils sont nettement vert olive au moins dans la partie subhepathique et suborbitale (terminologie de Rathbun sur *Sc. serrata*, jaune brun léger dans la même région dans *Sc. tranquebarica.*

A l'état frais, les différences de coloration de la face externe inférieure de la main du chelipède sont très nettes ; cette face est jaune vert pâle (banane) dans *Sc. oceanica* ; orange ou brun rouge tournant parfois au violet dans *Sc. tranquebarica*, rouge vif dans *Sc. serrata* et brun roux dans *Sc. serrata* var. *paramamosain.* Les doigts des chelipèdes sont jaune brun pâle dans *Sc. oceanica*, rouge violet dans *Sc. tranquebarica*, rouge feu dans *Sc. serrata*, rouge brun dans *Sc. serrata* var. *paramamosain.*

La coloration de la face ventrale de la partie antérieure de la carapace et du peristome est également caractéristique ; jaune vert pâle dans *Sc. oceanica*, jaune verdâtre dans *Sc. tranquebarica*, bleu vert (canard) dans *Sc. serrata*, rose bleuâtre dans *Sc. serrata* var. *paramamosain.*

Estampador attache de l'importance au développement plus ou moins grand d'un réseau reticulé rouge brunâtre sur diverses parties de la carapace et notamment sur les pattes, y compris les chelipèdes. Dans toutes les formes du Vietnam que j'ai examinés, ce réseau est, quelle que soit l'espèce, variable selon les individus sans qu'on puisse associer rigoureusement un certain degré de développement á une espèce particulière plutôt qu'à une autre; toutefois en accord avec Estampador les réseaux sont plus nets dans *Sc. oceanica* et *Sc. tranquebarica.*

J'ajoute que sur *Sc. oceanica* la face externe de la paume des chelipèdes porte des taches pigmentées foncées allongées et disposées en lignes longitudinales, bien visibles à l'état frais, mais persistant sur les specimens conservés à l'alcool.

CARACTERES MORPHOLOGIQUES

Les caractères distinctifs utilisés par Estampador sont d'abord examinés:

1°—Le rapport de la longueur des chelipèdes à celle de la carapace mesurée sur les mâles adultes. Dans *Sc. tranquebarica* la longueur des chelipèdes est d'après Estampador beaucoup plus de deux fois la longueur de la carapace; tandis qu'elle n'est que de deux fois cette longueur dans *Sc. oceanica.* Les mesures effectuées sur mes spécimens montrent que les chelipèdes sont seulement relativement plus courts dans *Sc. oceanica :* ceux de *Sc. tranquebarica* ne sont plus longs que dans une proportion très faible; et sur aucun de mes specimens

NOMS DES ESPÈCE	—	ECHANTILLON MESURE			
		♂ (E. 18055)	♂ (E. 17973)	♂ (E. 18038)	♀ (E. 18061)
Scylla oceanica	*Long. chelipède* / Long. carapace	73 / 41	110 / 58	113 / 62	131 / 84
		♂ (E. 18039)	♂ (E. 18158)	♂ (E. 18834)	♀ (E. 18160)
Scylla tranquebarica	*Long. chelipède* / Long. carapace	69 / 40	120 / 63	205 / 106	135 / 75
		♂ (E. 17969)	♂ (E. 18036)	♂ (E. 17970)	♀ (E. 18136)
Scylla serrata	*Long. chelipède* / Long. carapace	68 / 40	100 / 57	114 / 67	159 / 77
		♂ (E. 18053)	♂ (E. 17975)	♂ (E. 17974)	♀ (E. 17976)
Scylla serrata var. paramamosain	*Long. chelipède* / Long. carapace	70 / 40	103 / 58	120 / 64	111 / 60

de cette dernière espèce la longueur du chelipède atteint le double de la longueur de la carapace. Sur un seul specimen *Sc. serrata s.s.* (E. 18.136) la longueur du chelipède dépasse très légèrement le double de celle de la carapace. Mes observations ne permettent pas de confirmer la valeur attachée par Estampador à la taille des chelipèdes: longueur totale ou contour de la main. Les figures d'Estampador ne permettent aucune comparaison car elles comportent selon les espèces soit des mâles, soit des femelles. Enfin il est très difficile de mesurer la longueur exacte du chelipède qui ne s'allonge pas complètement ; si on prend soin de mesurer toujours le plus grand chelipède (d'ordinaire le droit), et toujours sur des mâles, on note que le rapport varie avec la taille et l'age des *specimens :* l'emploi de ce caractère distinctif est donc délicat.

2°—La variation de profondeur du sillon en forme d' H sur la région cardiaque de la carapace est d'après Estampador mieux marquée dans *Sc. oceanica* et Sc. *tranquebarica* que dans les deux autres formes. Sur les specimens du Vietnam, je n'ai rien remarqué de net à ce sujet entre les différentes espèces et je ne pense pas que ce caractère soit utilisable.

3°—La variation de l'épine externe à la base du doigt du chelipède. Estampador use de ce caractère pour différencier *Sc. serrata* de sa variété, indiquant qu'elle est absente ou presque dans *Sc. serrata*, un peu mieux développée dans la variété ; il précise par ailleurs qu'elle est bien développée dans les deux autres espèces *Sc. oceanica* et *Sc. tranquebarica*. Sur les specimens du Vietnam, cette épine est bien développée dans *Sc. oceanica* et *Sc. tranquebarica*, très faible dans *Sc. serrata* et mieux développée dans sa variété *paramamosain*, comme le montrent mes figures des chelipèdes des quatre espéces. L'épine du bord antéro-inférieur externe du carpus est peu développée dans *Sc. oceanica*, un peu mieux dans *Sc. tranquebarica*, encore plus dans *Sc. serrata* var. *paramamosain* et absente dans *Sc. serrata*. Ici encore il convient de toujours comparer des specimens mâles et sensiblement de même taille. Sur les femelles les épines sont d'ordinaire mieux développées.

4°—Les dents frontales—Estampador signale seulement à ce sujet que dans *Sc. serrata* var. *paramamosain* les dents frontales médianes son. légèrement plus avancées que les latérales Je. ne retrouve pas ce caractère sur mes specimens du Vietnam ; sur tous en effet à quelqu'espèce qu'ils appartiennent, je remarque que la paire de dents médiane est légèrement en avant des autres paires. Cependant, quelle que soit la taille (l'âge) des specimens, les dents frontales sont plus ou moins aigües en relation avec l'espèce du specimen ; elles sont toujours aigües dans les specimens de toute tailles de *Sc. oceanica* et au contraire toujours très arrondies dans ceux de *Sc. serrata s.s.* Dans les deux autres formes elles présentent des caractères

Mensuration de la carapace	ESPÈCES			
	Cua chuôi (crabe blanc)	Cua Sen (crabe vert)	Cua lua (crabe rouge)	Cua lan (crabe roulant)
	Sc. oceanica	*Sc. tranquebarica*	*Sc. serrata*	*Sc. serrata var. paramamosain*
Plus grande largeur entre les dernières épines..	87	93	89	94.5
Largeur du bord postérieur de la carapace ..	29.5	28.5	27	29.5
Largeur entre les épines extraorbitaires ..	49	50	51	49
Largeur entre les épines internes sous orbitaire ..	29.5	30	31	29.5

intermédiaires beaucoup moins accentués; dans *Sc. serrata* var. *paramamosain*, elles sont moins aigües que dans *Sc. tranquebarica* mais un peu plus que dans *Sc. serrata s.s.* Ce caractère n'est pas signalé par Estampador mais est nettement visible sur ses photos ; en particulier les dents frontales aigües sur *Sc. oceanica* de la pl. I, fig. 2.

J'ajoute les caractères suivants:

1°—La largeur du bord postérieur de la carapace est plus grande dans le *Sc. oceanica* que dans les trois autres espèces ; de même cette largeur est plus grande légèrement dans *Sc. serrata var. paramamosain* que dans *Sc. tranquebarica.*

2°—La longueur de l'espace entre les dents extra-orbitales ét celle de l'espace entre les dents sous-orbitales sont comparativement plus petites dans *Sc. oceanica* que dans *Sc. serrata* ; de même elles sont plus petites dans *Sc. serrata var. paramamosain* que dans *Sc. tranquebarica.*

Autrement dit dans des specimens de même taille les carapaces de *Sc. oceanica* et *Sc. serrata var. paramamosain* sont antérieurement plus étroites et postérieurement plus larges comparativement aux autres formes.

3°—Les dents antéro-latérales de la carapace presentent également dans ces espéces de légères différences, particulièrement nettes si on examine ces dents sur la face ventrale. Elles sont comparativement plus aigües dans *Sc. oceanica* et surtout d'une forme particulière plus renflée à la base ; elles sont aussi plus courtes ; ce sont les dents de *Sc. serrata* qui en sont les plus voisines pour la forme et les dimensions.

Conclusion

Les caractères morphologiques distinctifs examinés dans cette étude demandent à être vérifier sur de nombreux spécimens et les présentes observations sur la distinction des espèces n'ont de valeu'r que comme hypothèse de travail et suite à celles d' Estampador. Un fait parait certain c'est que le genre *Scylla* englobe plusieues formes dont deux au moins peuvent avoir rang d'espèce (1), les deux autres rangs de variété. L'étude de la répartition de ces formes distinctes dans les divers pays du Sud-Est Asiatique se justifie pleinement par leur importance économique.

Estampador indique que les espèces ont une bionomie différente, point que je n'ai pu vérifier avec exactitude au Vietnam ; d'autre part il signale et mes observations le confirment, que certaines espèces (*Sc. oceanica*) atteignent une grande taille, les autres non, la distinction de ces espèces est du plus grand intérét pour orienter les essais d'élevage. L'élevage des *Scylla* est actuellement pratiqué aux Philippines (Arriola). Son développement intéresse l'économie alimentaire des pays du Sud-Est Asiatique. La mise en commun des résultats des études poursuivies à ce sujet dans les pays membres du C.I.P.P. entre donc dans le programme de cet organisme et c'est le sens donné à cette communication.

(1) Autant que j'ai pu en juger par un examen rapide ; c'est *Scylla tranquebarica* que l'on trouve sur les marchés de Madras. De même l'examen des *Scylla serrata* de la Collection de l'Indian Museum du Calcutta, que m'a obligé permis de faire M .Tiwari, a suffit à me montrer que sous ce même nom étaient déterminés au moins deux formes différentes.

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11

INDIGENOUS MARINE FISHING GEAR OF THAILAND SUPPLEMENTARY NOTE

by

Swarng Charernphol *

ICHOK (Shrimp Scoop Net)

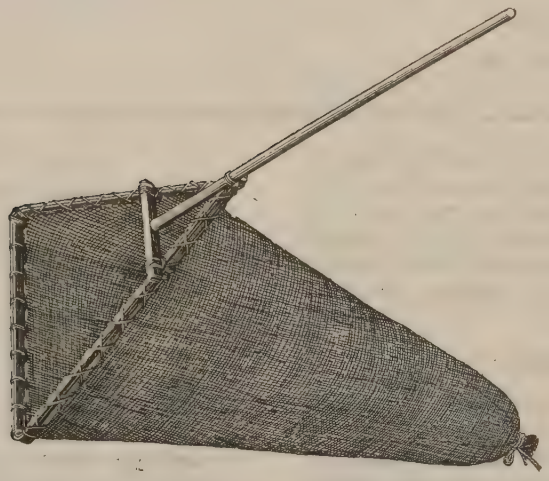

FIG. 1. Ichok (Shrimp Scoop Net).

Construction Gear consists of a bag net fastened to a triangular frame. Net about 1.7 m long, made of No. 20, 4-ply cotton twine, with 0.2 cm mesh. Mouth of net just big enough to fit around the frame, bottom of net tapered to about 15 cm in diameter. Frame made of either wood or bamboo rods about 2½ cm in diameter; front about 0.8 m and sides about 1 m in length, tied together firmly with string. A wooden or bamboo handle about 1.2 m long is fixed at the narrow angle end of the frame, and is strengthened by a short cross bar. The edge of the net is firmly tied to the frame with strong hemp string.

Fishing Operation Fishing is done both by day and night along the shore in shallow waters about 0.3–1½ m deep, with muddy or sandy bottoms. The net is held under water in front of the fisherman while he walks forward slowly. The catch is emptied into a basket hanging on the shoulder of the operator. In good fishing seasons as much as 50 kg of shrimps may be collected in one day; 5-10 kg is the usual daily catch.

Catch Mainly shrimps suitable for making paste ; some Stolephorus also caught.

Distribution of Gear Along the East and West Coasts of the Gulf of Thailand.

CHA NANG CHON KUNG (Bamboo Shrimp Scoop)

Construction A very handy scoop for collecting shrimps. Made entirely of bamboo material. The frame is semicircular in shape, front (straight side) is about 60 cm long, made of

* Fisheries Department, Bangkok, Thailand. The writer wishes to acknowledge thanks to Dr. S. W. Ling, Assistant Regional Fisheries Officer, FAO Regional Office for Asia and the Far East, (Bangkok) for his assistance in the preparation of this report.

bamboo splits. Bottom of bamboo scoop is made of fine screen, its hind portion forms a shallow pocket.

This gear is used all the year round for collecting shrimps from freshwater and brackish waters. The catch is mainly for subsistence purposes. — Fishing Operation

SWING TAK PLA-MUIK (Squid Dip Net)

Design of gear similar to an ordinary dip-net, consisting of a small shallow net and a bamboo handle. Ring of net about 40 cm in diameter, made of galvanized wire of 0.4 cm in diameter. Net about 40 cm deep, made either of cotton or of ramie twine, with 2 cm mesh. Handle of net made of bamboo rod, about 1½ m long and of 2 cm in diameter. — Construction

Net used by fisherman operating from a small rowing-boat 4.5 m long. — Fishing Operation

Fishing is done only on dark nights, along the coast, in water 6-10 m deep with sandy or muddy bottom. A medium size kerosene lamp is lit to attract squid. Bait consisting of small shrimps or small pieces of fish, is sometimes thrown into the water to induce squid to come near the boat. As soon as the squid appear the net is thrust into the water and with a quick action the squid are scooped up from behind.

Squid. — Catch

Around Goh Chang Area in the East coast of the Gulf of Thailand. Fishing season starts in October and ends in January ; November gives the best fishing. — Distribution of Gear

PA BANG (Simple Shrimp Seine)

Net 12 m long and 2.52 m high, made of 4-ply No. 20 cotton netting, with 0.2 cm mesh. Head line and ground line are made of cotton ropes about 0.5 cm in diameter. Lead weights are about 3 cm long and 0.15 cm thick, spaced 57 cm apart. — Construction

The gear is operated by two or three fishermen from a small rowing-boat of 5-6 m long. Fishing is done in shallow shore water about 1.50—2.00 m deep, with sandy or muddy bottom. — Fishing Operation

When a school of shrimp is located, two fishermen, each holding an end of the net, jump into the water and drag the net across the school toward the shore. The catch is kept in the boat.

Small species of shrimps (for shrimp paste) and small fish. — Catch

Along both coasts of the Gulf of Thailand, especially Goh Chang area. Fishing season August to November. — Distribution of Gear

UAN PLA LAMAWH (Mullet Encircling Net)

Net made of ramie twine, with 3 cm mesh. Each unit is 20 m long and 2 m high, and 10-11 units make one complete set. Head and ground lines are both hemp, about 0.6 cm in diameter. Wooden floats are 4 × 4.5 × 2 cm in size, spaced about 32 cm apart. — Construction

Small rowing-boat about 6 m long, carrying a crew of three. — Boat

Fishing is done during day in shallow waters about 1–2½ m deep, with sandy or muddy bottom. Method of using this net is similar to that described for the Mullet Gill Net, but the fish are gilled to the net. — Fishing Operation

Mullets. — Catch

Trat Province, East Coast of Gulf of Thailand. Fishing is carried on all the year round,, but November and December are the best months. — Distribution of Gear

UAN LOI PLA-INSI (Drift Gill Net for King Mackerel)

Construction — Net made of No. 20, 18-ply cotton twine netting, with 11 cm mesh. Each unit of net is 20-22 m long and 2.5 m high, and 10–16 units make one complete set. Both head and ground lines are made of cotton rope, about 0.5 cm in diameter. Floats are wooden blocks, 17 × 6 × 3 cm in size, fixed to the head line, spaced equidistantly about 32 cm apart.

Boat — Small sail boat about 6 m long is used, carrying a crew of 2-3 fishermen.

Fishing Operation — Fishing is done mainly during dark nights. Net is set in waters 8-20 m deep, at an angle of about 90 degrees in relation to the direction of current. One end of the net is tied to the boat while the other is free. The boat and net are allowed to drift. The net is hauled at about 3–hour intervals to remove the catch.

Catch — Mainly King Mackerel, but sharks, rays, cat-fish, butter-fish and other Scomberoides are also caught. The catch is divided into 5 shares ; boat and gear get one share each, and the rest is equally divided among the fishermen.

Distribution of Gear — Along the East and West Coasts of the Gulf of Thailand.

UAN KUNG (Shrimp Encircling Net)

Construction — This is a simple encircling net made of No. 20, 4–ply cotton twine, with 3 cm mesh. Each unit is about 10 m long and 1.5–2 m high, 5 units make one complete set. Head and ground lines are hemp ropes of 0.6 cm in diameter. Wooden floats cylindrical–shaped, 5 × 4 cm in size, fastened to the entire length of the headline equidistantly about 32 cm. apart. Each end of the net is provided with a wooden beam about 80 cm long and 4 cm in diameter.

Fishing Operation — The net is operated by a crew of 3 fishermen from a small sampan in shallow waters, 1–2 m deep, along the coast. Fishing is done only in the daytime, by two fishermen, each holding one end to encircle the shrimps. The net is hauled and the catch taken into the boat. As much as 100 kg of shrimps has been taken in one haul, but the usual amount is around 5-10 kg.

The catch is divided into 4 shares; boat and gear each gets one share and the rest is equally divided among the fishermen.

Distribution of Gear — In Trat Province, fishing is done all the year round, but May and June are the best months.

LUK YAE MEING-LANG (Shrimp Barrier Net—Indochina type)

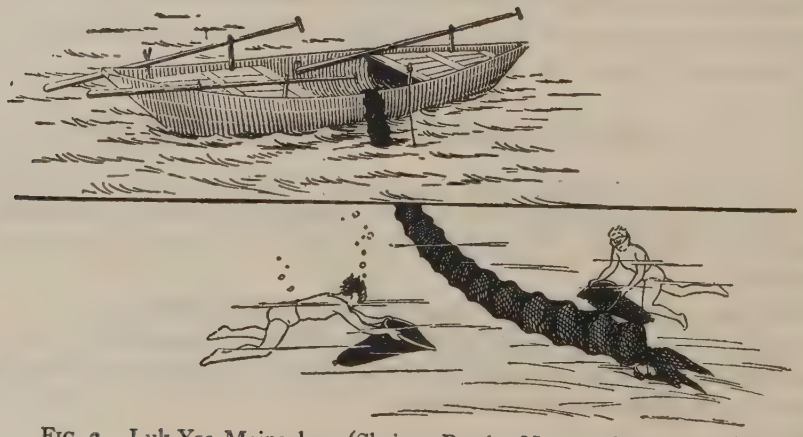

FIG. 2. Luk Yae Meing-lang (Shrimp Barrier Net—Indochina type).

Construction — This gear consists of a long sheet of cotton netting rolled around a number of rattan rings. The netting is about 6-7 m long and about 1 m wide, made of No.

20/12-ply cotton twine. Each rattan ring is fixed to the net by four hemp strings; the rings are spaced about 30 cm apart. Both ends of the net are tied and provided with a piece of 10-12 m long hemp rope. A stoneweight of about 4 kg is attached to each end of the net. An ordinary scoop net is used as accessory gear.

Boat

Small sampan, 5-6 m long, is used.

Fishing Operation

This gear is used by a team of 3 fishermen : one managing the boat and the other two operating the gear. Fishing is done by day and night along the coast in shallow waters about 2-10 m deep, with either sandy or muddy bottom. As soon as a school of shrimps is located the gear is lowered into the water in front of the path of the moving shrimps. Upon reaching the gear, most of the shrimps stop moving forward and crawl on it. Scoop nets provided with long handles are then used to collect the shrimps. In deeper waters, the fishermen, armed with simple scoop nets, dive down to do the collecting.

Distribution of Gear

Around Goh Chang area. Fishing season starts from August and ends in November. September and October are the best fishing months.

LUK YAE THAI (Shrimp Barrier Net—Thai type)

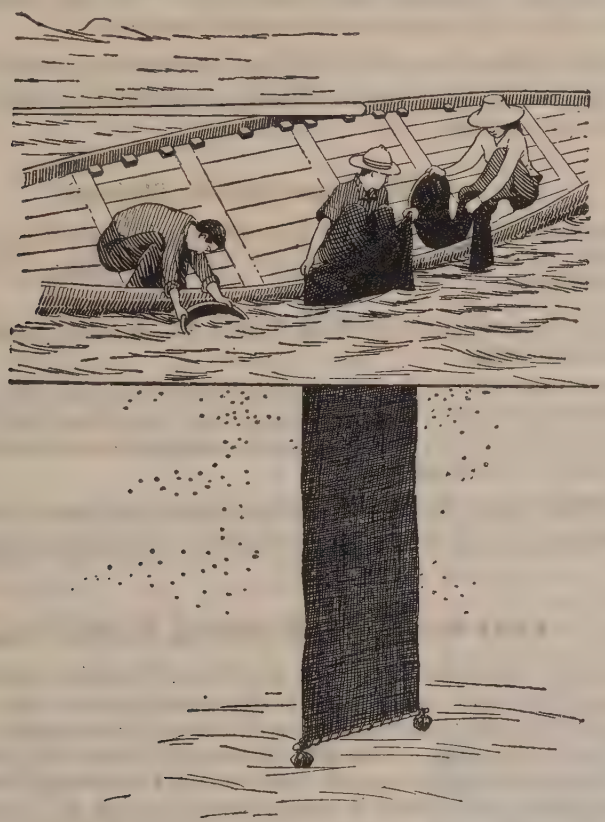

Fig. 3. Luk Yae Thai (Shrimp Barrier Net—Thai type).

Construction

Made of a sheet of simple cotton netting about 6.5 m long and 1.5 m high, with 0.2-0.3 cm mesh. One end of the net is provided with a wooden beam about 1.6 m long and 2 cm in diameter. At each end of the wooden beam a stone-weight about 2½ kg is attached. Scoop nets of both circular and semicircular openings are used as accessory gear.

Fishing Operation — The gear is operated from a small sampan by 2–3 persons. Fishing is done during the daytime along the coast in shallow waters 1–6 m deep. When a school of shrimps is detected the end of the net which is provided with beam and weights, is lowered into the waters in front of the shrimps. It is lowered gradually until it touches the bottom and the other end is tied to the boat. Shrimps, on reaching this barrier net either crawl upward or swim to the surface of the water. They are then collected with scoop nets.

Catch — Mainly small shrimps suitable for making paste. The highest record of catch per day is 200 kg. Average catch is 10 kg per day.

Distribution of Gear — Along the East Coast of the Gulf of Thailand especially in Goh Chang area. Fishing season is from August to November.

LAMUHIN or HINWONG (Stone Block Trap)

Construction — Stones of various sizes are piled into a long semicircular bund at a corner of the seashore. The bund is about 40-60 cm high and has a radius of 30-50 m.

Fishing Operation — During high tide the whole bunded area will be flooded with sea water, and littoral fish of various kinds are carried in by the current. The fish are stranded at ebb tide and are then collected by fishermen with simple hand gear.

Catch — Small littoral fish such as mullets, shrimps and crabs and sometimes sharks and rays.

Distribution of Gear — Along both coasts of the Gulf of Thailand, especially in Goh Chang area, fishing is done all the year round.

KRUI (Brush Pile for Shrimp)

Construction — Brush piles are constructed along the banks of estuaries. 50-70 pieces of tree branches, each of about 1-1.5 m long, are required for making one pile. The distance between two piles is 8-10 m.

Bait — Mixture of rice bran and clay (bran 4 parts, clay 5 parts) made into balls of about the size of a duck's egg.

Fishing Operation — Fisherman visits the brush piles every day during low water by a small rowing boat. Baits are laid around the pile, one piece at one spot. In about half an hour, shrimps from the brush pile and its vicinity will gather around to take the baits. An ordinary cast-net is used for catching them.

Catch — Mainly long-legged shrimps (Macrobrachium), and some Penaeid shrimps also.

Distribution of Gear — Trat Province, on the East Coast of the Gulf. July and August are good fishing times.

LUAB KUNG LUANG (Shrimp Bamboo Trap)

Construction — Barrel-shaped trap, about 72 cm in height and 26 cm in diameter at both ends. Three strong rattan rings are used as the framework, one at each end and the third at the centre of the trap ; the other parts of the trap (principally bamboo splits) are firmly built on to the rings. Two sets of trapping deivce are provided : one at the entrance and one at the middle portion of the trap. The bottom of the trap is provided with a wooden door, semicircular in shape, through which the catch is removed. Two dozen or so of bamboo poles are used for construction of a simple ' V '-shaped wing leading to the entrance of each trap.

Fishing Operation — Traps are set in shallow waters of the estuaries. Each fisherman is capable of operating 20-40 of these traps. Traps are hauled up every day to remove the catch. Baits, when used, are placed at the centre of the trap.

Catch — Mainly long-legged shrimps (Macrobrachium).

Distribution of Gear — Popular in all brackish-water area of the Gulf of Thailand, especially in Trat Province.

SHOM TANG MUIK (Bamboo Harpoon for Squids)

This gear consists basically of a bamboo pole 1½-2 m long and 3-4 cm in diameter. The larger end of the pole is split into 8-10 parts for a distance of about 30 cm. The tips of these sections are sharpened. A wooden disc with slightly larger diameter than that of the pole is inserted into the opening of the large end, between the splits, and is pushed gently down to a depth that gives the desired degree of spread to the splits. The regions in front of and behind the inserted disc are then tightly bound with strong hemp string. — Construction

Used as any other harpoon. Fishing is done along the coast on dark nights. A small sampan is used, carrying two persons; one handles the harpoon and the other manages the boat. A lighted lamp is hung on a short pole to attract squid. — Fishing Operation

Squid. — Catch

In Goh Chang area, fishing is done the whole year round. — Distribution of Gear

12

A CONSIDERATION OF THE CLASSIFICATION OF FISHING GEAR AND METHODS

by

T. W. BURDON *

ABSTRACT

A review is given of a few papers which have presented classifications of fishing gear and reasons are given for regarding these as unsatisfactory. The 'true' properties of fishing gears are listed and their value as a basis for classification is discussed, and it is concluded that the precise manner of capture is the most characteristic feature of a gear. A classification based on this characteristic is offered.

The diversity of instruments used for the capture of fish and the widely differing nomenclatures of such gears necessitate the formulation of an effective system of classification as a preliminary to the enumeration of fishing methods in any area. Such a classification would simplify both descriptive and comparative work since, if the major property of the gear is accepted as the basis of the classification, the description would require only such additional information as would distinguish it from other gears of the same group.

EXISTING CLASSIFICATIONS

Various classifications have been proposed in the past, generally as a prelude to the systematic description of the fishing gear of a limited area. One of the most important of these was that propounded by Davis (1927), in which he divided the fishing gear of England and Wales into five major classes, i.e., fixed instruments, drift nets, movable drag nets, baited traps and man-power instruments. This classification was not satisfactory and Davis found it necessary to disregard it where, for the sake of simplicity and greater clarity, gear strictly belonging to one division could be more easily described and explained under another head. It will be observed that the first three classes are determined by the position of the gear during operation vis-a-vis the sea bottom, the fourth by the method by which the fish are brought into relationship with the gear and the fifth comprises a miscellaneous collection of gear, usually operated by one man. Thus it will be seen that the classes are of unequal determination and this alone constitutes a major objection to the validity of the classification. Moreover, consideration of certain local methods establishes the inadequacy of this system for the examination of the fishing gear of South-East Asia. For example, the large Chinese lift net with its supporting scaffolding and lever mechanism is normally used as a fixed instrument in Asia, but a similar net differing in detail only, is operated from boats in parts of Asia and Africa. Smaller versions of the net without a scaffolding and lever system are in common use throughout South-East Asia, one of these—the

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crab lift net being operated as a baited trap. In the classification proposed by Davis these nets would be separated into three distinct classes, but as the nets are so similar in construction and method of operation this is unwarranted. Pearson (1922) quotes an example of a drift net in Ceylon which may be used as a set net or as a seine, i.e. it would be classified as a fixed instrument, a drift net or a movable drag net depending upon its use at the particular time. In Malaya, such an illustration is not available but gill nets of similar design may be set or allowed to drift according to the wishes of the operator. This is particularly true of the small gill net used for the capture of ikan tamban (*Harengula* sp.), which may be attached to a fishing stake or operated from a drifting boat in conjunction with a coconut leaf lure.

The Burma Fisheries Act (No. III of 1905) includes a schedule of fishing implements which are divided into fourteen groups. Although for the purposes of licensing and revenue collection this classification may be adequate, there are many objections to its wider use. In particular, the groups have been based on various features including size, design, the precise mode of capture, the location and the actual method of operation. For example, Group B—Drift & Float Nets, differs from Group C—Plain Fixed Nets, in minor detail only, and the individual nets in each group show wider variation than do the groups themselves. Group F—Purse, Pouch or Bag-nets : includes all bag-shaped nets into which fish enter voluntarily or are carried by the current, and they differ from Group G—Anchored Entrapments only in so much as the latter are constructed from split bamboo. Furthermore, group F includes a surface trawl which has more in common with the drag nets than with the filter nets which largely compose this group. Group M—Miscellaneous is, of course, a most unsatisfactory division as it contains a heterogeneous collection of methods including spears, plunge baskets, boats with jumping platforms, poisons, explosives, fish smothering and collection by hand. The differentiation between obstructions not closing a water-way (Group L) and those doing so (Group N), while of great conservatory importance, cannot be accepted as a basis for classification, since both may operate as set barriers. For example, the yindan in Group L includes barriers set across and enclosing a river or backwater.

Pearson (op. cit.), in his description of the fishing appliances of Ceylon, classified the nets according to their method of operation but held rigid classification to be impossible because nets are frequently used in different ways on different occasions. His classification recognised the following major groups :—Fixed Stake Nets ; Fixed Net with Bag ; Seine Net with Wings and Bag ; Drag Net ; Vertical Gill Net (with floats at top and weights at bottom) ; Gill Net (without floats or weights) ; Gill Net (floating, not vertical) ; Horizontal Net ; Casting Nets ; Circular Gill Net ; Fish and Crab Traps ; Line and Hook ; *Kottus* (Fish Shelters) ; Spears ; Landing Nets and Sundry Devices. Unfortunately the descriptions are often inadequate for detailed consideration but it is clear that the classification is not valid, since gears in which the method of operation differs have been included in the same group. For example, fixed stake nets include not only complicated fishing stakes and simple filter nets but also the *Kondadi valai*—a typical drive-in net. The latter is similar to the *Vadu valai* (a gear which is in a separate group) " except that it is not supported by stakes ", and it would appear that Pearson has confused design with the method of operation. Similarly fish and crab traps include baited lift nets and gears with non-return devices in which the method of capture is similar, i.e. they are used to trap the catch, but the detail of the operation is very different. Fish traps with non-return devices do, in fact, show a closer resemblance to some of the large fixed stake nets than they do to the baited lift nets.

Hornell (1925 & 1938), in a description of the fishing methods of the Madras Presidency, does not propose any specific classification but he describes the gears in a systematic manner, particularly in his later paper. In a recent book published posthumously (Hornell, 1950), he extends the scope of this work and adds much to comparative knowledge of fishing gear. The book, although systematic in conception, contains no general consideration of all fishing gear, various groups being considered by their evolutionary origin, the precise method of capture employed, the mode of operation, the species taken or the method in which the fish are brought into relationship with the gear.

Tham Ah Kow (1949) summarises the main fishing methods utilised in Malaya and employs a classification in which the principal divisions are nets, lines, traps and miscellaneous methods, a classification in which the last division includes spears, explosives and poisons. Apart from the objection to classifying widely divergent methods of fishing under the single head ' Miscellaneous ' this classification, like that proposed by Davis, includes determination by constructional design, e.g., nets and lines and by method of operation, e.g., traps. In consequence the classification contains several anomalies, for example set barriers may consist of stone or earthen bunds and may include entrapment devices; in either case such gears could not be

classified as nets. Certain of the less complex traps, e.g., the *ambai* and *jermal* are very similar to gears included as nets and the major sub-division of nets into moving and stationary gears is clearly unsatisfactory as gillnets may be used either set or drifting as the occasion demands. Moreover, nets in which movement is an essential part of the operation, e.g., seines and castnets, are grouped with drift nets in which the movement is of subsidiary importance. On the other hand, the raising movement of lift nets is an operative feature although the gear may or may not be geographically stationary.

There are, no doubt, other classifications to which the author has not had access but it is clear that none proposed to date can provide a suitable basis for the detailed consideration of the fishing gears of more than a restricted area. It is, therefore, desirable to examine the principle on which a valid classification could be constructed.

THE PRINCIPLES OF CLASSIFICATION

A valid classification of fishing gear and methods can be determined only by the recognition and appraisal of their essential properties. These attributes can be summarised as follows :—

1. The precise manner in which capture is effected.
2. The method by which the fish are brought into relationship with the gear.
3. The actual method by which the gear is operated.
4. The power required for operation.
5. The constructional design.
6. The materials for construction.
7. The location of operation.
8. The species captured.

1. Precise Manner in which capture is effected

The actual point, which is to be determined in assessing the precise manner by which capture is effected, is that at which the fish is restrained or possibly killed. Thereafter it is either removed directly from the water by the gear, or is brought to or held in a condition in which it may be so removed, its chances of escape being negligible. It is clear, therefore, that the method by which the fish is brought into relationship with the gear, e.g., the use of bait or guiding barriers, and the subsidiary technique of removal from the water are to be disregarded in this consideration.

The methods can be summarised as follows :—

1. INDIVIDUAL OR SPECIFIC

Methods in which individual fish are the subject of capture operations.

Precise Manner in which capture is effected	Type of Gears	Remarks
1.1 To seize or grasp.	Manual collection of fish and shell-fish, artificial fish-holes, octopus pots, plunge baskets, etc.	A simple and clear-cut division which includes those methods which have been developed from manual collection to render it more effective, e.g., the construction of artificial fish-holes in the bank of a stream from which the fish are subsequently removed by hand (Burma & India), and the use of earthenware pots in Japan, Italy, etc. for the capture of octopuses. The snare line (*Valla vala* of the Madras Presidency) is an excellent illustration of the development of manual collection—the line, which is ornamented with young coconut palm leaves, being used to scare the fish towards the operator.
1.2 To rake.	Rakes.	Comb-like instruments operated by drawing through sand or mud, or used for detaching shell-fish from rocks.
1.3 To strike or hit.	Jungle knife.	In certain fresh-water fisheries of Malaya, a *parang* may be used to strike at and disable fish which are attracted to the operator, who carries a lighted torch. The use of a sickle in the Madras Presidency is, however, more akin to hook fishing as it is mainly used as a *gaff*. This is also true of the *Malu kottanakaduwa* of Ceylon.
1.4 To snare.	Snares, loop-fishing.	Snares and loop fishing secure the fish in a loop of twine or wire. Various methods are used to bring the fish into relationship with the snare, e.g., baits, lures, searching.

Precise Manner in which capture is effected	Type of Gears	Remarks
1.5 To choke.	Bait-holder or gorge, baited.	These instruments consist of a small rod tapering to a point at each end and attached in the centre to a line. Fish taking the bait with which it is furnished are secured, the gorge resisting withdrawal. The baited spring gorge (India) is constructed of flexible bamboo. It is set by bending the ends together securing them in an insect which forms the bait.
1.6 To hunt with trained animals.	Cormorants, sucker fish, otters and dogs.	The capture of fish by the use of trained animals is found in Asia, America, Australia and Europe.
1.7 To impale.	Spears, harpoons, arrows and darts.	This is a clear, well-defined division requiring no further comment.
1.8 To hook.	Hand-lines, rod and lines, long-lines, troll-lines, jigs, gaffs.	A well-defined group in which capture is effected by the penetration of a curved point. Hooks may be single or multiple, may be barbed or not, and the methods by which the fish are brought into relationship with the gear may vary.
2. INDISCRIMINATE OR DIFFUSE		
Methods, which are usually indiscriminate or diffuse in action, affecting all fish within the area of operation.		
2.1 To poison.	Poisons.	The use of toxic substances to stupefy or kill fish is widely distributed throughout the world, a fact which suggests its early origin.
2.2 To suffocate.	Fish smothering.	This is an ingenious method, employed in waters of low oxygen-content, in which air-breathing fish are killed by denying them access to air.
2.3 To stun.	Explosives.	The use of explosives to stun or kill fish, although of comparatively recent origin, is widely distributed in spite of the fact that it is illegal under most fisheries legislation.
3. MULTIPLE OR COLLECTIVE		
Methods, in which generally a group or association of fish are the subject of capture operations.		
3.1 To enclose.	Set barriers, fish weirs, etc.	Fishing gears in which capture is effected by means of a simple barrier which prevents the escape of fish from a natural area which they have voluntarily entered.
3.2 To screen.	Filter nets and stake nets including *ambais, jermals* etc.	Instruments set in moving water, with or without guiding barriers, which effect capture by screening out the catch which is prevented from leaving the trap by the force of the current.
3.3 To confine.	Portable fish traps, certain fishing stakes, tubular traps, thorn-lined traps.	Structures which permit ready access but from which exit is hindered or prevented by a structural non-return device.
3.4 To restrain in air.	Jumping platforms with barriers, anchovy boards, platform and verandah nets, pit-falls.	Instruments which effect capture by exploiting the habits of certain fish which readily leave the water, e.g., mullets, the fish being encouraged to do so by the use of an apparent obstruction. It is usually accompanied by scaring and their return to the water is prevented by a pit or intricate obstacle.
3.5 To enfold by raising or lowering a structure.	Liftnets, drop nets, cast nets, thrust or push nets, dip and scoop nets.	Structures which are raised or lowered to trap fish below or above them.

Precise Manner in which capture is effected	Type of Gears	Remarks
3.6 To mesh or entangle.	Drift and set gill nets, encircling and drive-in gill nets, tangle nets, trammel nets.	Netting or similar structures in which capture is effected by the actual meshes, either by gilling in an individual mesh or by tangling the fish in several meshes.
3.7 To engulf.	Drive-in and closing bag nets, clap nets, pouch nets.	Structures in which capture is effected by engulfing the fish which enter the gear voluntarily or as the result of scaring, the capture not being completed until the gear is closed.
3.8 To invest.	Seines, dredges, trawls, purse seiens, lamparas, snap nets.*	Structures in which capture is effeeted by investing the fish, the capture being completed by raising the gear.

It will be seen that this principle provides a reasonable basis for an outline classification, although it is to be admitted that difficulties will be encountered in the case of individual gears operated in more than one manner, where the precise method in which capture is achieved differs. The case of a gill net operated as a seine, e.g., the Parrot fish gill net of Hongkong, illustrates this difficulty, but it is unlikely that such a practice is common, particularly in view of the continued development of fishing methods. Clearly a dual purpose gear may be of advantage in a primitive community, but its survival in the face of the competition existing in the more-specialised fisheries will be rare.

Individual or specific methods of capture form a well-defined division except for those in which use is made of trained animals. This particular group contains a heterogenous collection of methods in which the sole similarity is the use of a trained animal. The animal may be employed in the actual capture operations, e.g., sucker-fish and cormorants ; may simply locate and keep the fish engaged while capture is effected by hand, e.g., dogs ; or may drive the fish into a net or other structure, e.g., otters. In view of the very specialised nature of the operations it is, however, considered desirable to group the methods in spite of the differing manners in which capture is effected. It may also be argued that the use of rakes and striking implements is only preliminary to manual collection and there is little doubt that this is true in the case of the former. In the latter case, however, a well-aimed blow may kill or seriously injure the fish and render the subsequent method of capture one of minor importance. This method is, however, clearly a development of manual collection and can be considered as such, although in the preceding summary both methods have been separately included for clarity.

The position of the plunge-basket may also be questioned on the grounds of its similarity in operation to both the set barrier and to a lesser extent, the purse seine. This fishing gear consists of a sub-conical basket, open at each end, with an extension of the frame into a series of short spikes at its broader perephery. It is operated in muddy padi-fields or marshy areas by plunging it into the water and pressing the bottom firmly into the ground, any fish that may be trapped within the basket being removed by hand. It has, however, been included as a form of manual collection, of which it is clearly a development, the actual capture being effected by grasping the catch with the hand. Furthermore, although the fish is restrained in the first place by the gear, in soft muddy areas, it may escape by burrowing.

Indiscriminate or diffuse methods of capture form a homogenous division in which the method is directed at the fish within a certain area. It is characterised by the fact that the fish are rendered inactive by the method employed and can, therefore, be collected without difficulty. It may be argued that these methods are not necessarily methods of capture but are used as a preliminary to the manner in which the fish are actually secured. For example, explosives are used to quieten ' wild ' tuna in order to permit encirclement by a purse seine. The degree of restraint imposed in this case depends on a number of factors, one of the more important of which appears to be the distance of the fish from the actual point of explosion. Obviously nearby fish are killed or fully restrained and their subsequent collection in a purse seine is merely a question of the subsidiary technique of securing the catch.

Multiple or collective methods of fish capture include all those gears in which the operations are directed at a group or association of fish, the capture

*The term snap net is used to describe small folding nets of laced banyan-bark strips operated by the aborigines of Arnhem Land. These nets are snapped open and shut with a horizontal movement investing any fish that are caught between the wings. (National Geographical Magazine, December, 1949. National Geographical Society, Washington).

of individual fish being incidental to the main operation. In this respect it stands distinct from the individual or specific methods and probably reflects fisheries development parallel to the progress of a primitive community from hunting to trapping.

2. The Method by which the fish are brought or come into Relationship with the Gear.

The study of the methods by which fish are brought or come into relationship with the gear necessitates a knowledge of the movement or pattern of distribution of the fish concerned. Clearly there are two broad patterns, the ' random ' movement which cannot be correlated with any physical factor or stimulus and in which no degree of freedom is lost by orientation to any vector, and that in which the fish orientate themselves to a stimulus. Accepting this major division, further differentiation can then be made in the latter group by the nature of the stimulus concerned. It is also desirable in certain cases to recognise that the nature of the stimulus can be resolved into its gross form and its intensity. Complications, however, arise as the information available regarding fish behaviour is limited and in consequence no classification based on this principle can be final or accurate at this stage.

Using this principle it is possible to group the more important fishing gear and methods as below :—

Method by which fish is brought or comes into relationship with the gear	Fishing Methods	Remarks
1. *" Random " Incidence*	Manual collection ; plunge baskets ; rakes ; spears ; long lines of unbaited hooks ; hunting by animals ; set barriers ; filter nets & stakes ; scoop nets ; push nets ; cast nets ; drop nets ; lift nets ; gill nets in still water ; manually operated bag nets ; dredges ; trawls ; seines ; purse seines ; poisons ; explosives and fish smothering.	Filter nets and certain fishing stakes which screen the catch from moving water are included as the fish do not orientate themselves to the current but are carried bodily by it.
2. *Orientated Incidence*		
2.1 Rheotactic	All gears utilising the orientation of fish to a current of water e.g., fish shelters with baited hooks, lift nets operating with coconut frond or other shelters ; certain fishing stakes, e.g., a *kelong* and *belat* with guiding barriers sited to obstruct movement in response to currents ; gill and tangle nets.	Gears in which the response of the fish to a current of water brings it into relationship with the gear, a response which may be with, against or across the current. It does not include filter nets in which the current carries small fish and prawns into the net, and it is typified by the salmon ' putcher ' used in the Severn district of England. This is a trumpet-shaped instrument into which a salmon, swimming in response to the stimulus of the current, enters and becomes fast.
2.2 Phototactic	All gears to which the fish are directed in response to the stimulus of light.	
2.21 Intensity	Jungle knife ; spears ; gaffs ; dip nets ; lift nets ; certain fishing stakes, e.g., *kelong* ; purse seines ; beach seines etc.	All gears to the area or range of operation of which fish are directed in response to the intensity of a light source.
2.22 Form	Use of visual lures in manual collection i.e., ' ratlure ' (Polynesia), spears, unbaited troll lines and hooks, unbaited traps.	Although lures used in various form of fishing probably stimulate the feeding responses of the fish, it is clear that there is a further fish behaviour mechanism which is visual, i.e., the inherent curiosity of certain fish. Unbaited traps rely upon this mechanism and the curiosity of *Stromateus* is so great that a shoal can be distracted by an operator in the water while the net is set around them.

Method by which fish is brought or comes into relationship with the gear	Fishing Methods	Remarks
2.3 Chemotactic		
2.31 Feeding Behaviour	Spears, poisons, set barriers, baited loop fishing, gorges, hooks, lift nets, dip and scoop nets; baited fish traps.	Includes all fishing gear in which feeding behaviour is exploited, i.e., all baited gears or gears in which "chumming" is used to attract fish. (Poison is included, as one form of fishing known in Malaya consists of introducing bait containing a stupefying substance into areas believed to be harbouring large fish.)
2.32 Other Chemotactatic Responses	Use of noxious fluids to drive fish into entrapments	
2.4 Sound and Other Scarer Devices	Manual collection, plunge baskets, snares (Tonga) lift nets, jumping or platform traps, drive-in and encircling gill nets, drive-in nets, seines, trawl nets.	This includes all gears in which scarer devices are used to direct the fish into the gear. A typical scarer device on a small trawl operated in Singapore consists of a group of shells attached to each warp. Jumping or platform traps include the employment of a device to ensure that fish leap a suspected obstacle, thereby falling into a trap. Some use is also made of a winking light as a scarer device. Clearly this is a phototactic stimulus and should further sub-division of the group be desirable, it should be included as such. In point of fact all scaring is the result of one or more stimuli and this group could be redistributed accordingly if detailed information was available as to the exact nature of the stimulus concerned.
2.5 Other Behaviour Responses	Manual collection with pot and shell lures for octopuses, cuttlefish pots with azalea lure, leaf lure and jigger for cuttlefish, pitfalls, platform traps.	The use of pitfalls may appear an unlikely method of fishing but in Burma they are used in conjunction with fish fences. Air-breathing fish, trying to make their way round the fence fall into the pits and are caught. Platform traps are similarly employed to secure fish trying to leap an obstruction across a water-way. Other methods of note include the use of a female cuttlefish to attract males which can then be secured.

Further sub-division of certain of the relationships established in response to stimuli can be made by the origin and scope of the stimulus. For example, in the case of chemotaxis it is possible to distinguish between natural stimuli, e.g., salinity gradients, and man-provided stimuli, e.g., baited gears and the use of noxious fluids. The latter group can then be further analysed by division into stimuli which attract fish to a specific gear, e.g., baited gears and those which provide a general orientation to the gear, e.g., noxious fluids.

It is clear, however, that this principle provides no basis for the determination of a useful classification of fishing gear. For example, fish may be brought into relationship with gears employing hooks by any of the methods concerned, other than the use of scarer devices and the extremely rare utilization of the movement of fish away from noxious fluids. Gill nets may be used with scarer devices, may intercept fish moving in response to water currents or may be the subject of random encounter. Furthermore, in the case of certain gears the method by which the fish is brought into relation with the gear may be modified during the actual operation of the gear. For example, the *kelong*, a fishing stake which is widely employed in Southern Malaya, may be operated in certain seasons during the day when it relies on the interception of fish moving in response to a current of water by a guiding barrier, which is an integral part of its construction. During the hours of darkness, however, a light is also employed which undoubtedly increases the catch,

apart from holding the trapped fish above the lift net. Lures of a similar character and structure may attract a variety of species through their response to varying stimuli. Hornell (1950) describes a lure which consists of a coir rope ornamented with strips of palm leaves in a chapter entitled " The Fatal Attraction of the Shadows ", but he also mentions a similar lure utilising different foliage to which flying fish are attracted by a reproductive stimulus. The orientation of fish collecting around palm-leaf lures in Malaya vis-à-vis the current suggests a rheotactic response, and there is no doubt that this assembly also provides the stimulus for movement of predatory fish into the area.

3. The actual Mode of Operation of the Gear

Although the actual mode of operation of fishing gear varies widely in detail, in basic character three distinct forms can be recognised as follows :—

1. *Passive or Accepting.*

This includes those fishing gears which accept and retain fish coming into relationship with them.

2. *Active or Searching.*

This includes fishing gears which actively seek and retain the fish, the relationship between the fish and the gear being imposed by the latter.

3. *Diffuse or Indiscriminate.*

Methods which are neither accepting nor searching, but in which all fish within the area of operations are affected indiscriminately.

It will be observed that this division resembles certain of the earlier classifications in which gears are divided by their geographical movement into moving or stationary methods. There are, however, certain gears which clearly demonstrate the difference between the systems and the inadequacy of the earlier classifications concerned. For example, troll-lines are moving gears but they are passive or accepting methods, the movement being the method by which the fish is lured into relationship with the gear. Similarly, plunge-baskets and purse seines are fixed geographically during operation but are in no way passive or accepting, the searching being carried out by the operators before the gear is set. This suggests that differentiation between active methods might be achieved by division into those in which the gear seeks the fish and those in which the fish is located by the operator before the gear is set. Such a distinction would, however, be purely artificial as there is in fact some conscious or unconscious location of the fish in all fishing methods. That is to say, before the gear is set the operator selects a locality in which he knows from experience that fish are likely to be found or in which there are certain physical features which suggest that fish are present.

Further sub-division by the detailed method of operation would necessitate consideration of the precise method of capture. Similarly, distinction between gears which employ luring or scarer devices introduces a consideration of the method by which the fish are brought or come into relationship with the gear. In either case the classification would involve the use of two principles which is to be avoided if possible. Using the actual mode of operation of the gear as a basis of classification the major gears can, therefore, be summarised as follows :—

The actual mode of operation of the gear	Type of Gear
1. *Passive or Accepting.*	Loop-fishing ; baited hooks ; anchored unbaited hooks ; troll lines ; set barriers ; fish weirs ; filter and screen nets ; fish traps ; some aerial traps ; lift nets ; drive in and closing bag nets ; gill and tangle nets.
2. *Active or Searching.*	Manual collection ; rakes ; snares ; trained animals ; spears ; harpoons etc. ; long lines of unbaited hooks (when trawled) ; drop nets ; cast nets ; thrust nets ; dredges ; seines ; lamparas etc.
3. *Diffuse or Indiscriminate.*	Poisons, explosives and fish smothering.

It is clear, therefore, that this principle offers no satisfactory basis for a detailed classification of fishing methods. Further, were it adopted, it would be necessary to use it in conjunction with other principles in order to obtain a detailed division.

4. The Power required for Operation

The amount of power required for the operation of fishing gear is of great importance in the assessment of costs of production, but it is of little value

as a basis for classification of fishing gear. Power requirements necessitate a study of not only the number of men engaged and the mechanical energy required for hauling, but also of the wind or mechanical force utilized to draw trawls and other moving gear through the water. Difficulties will be experienced in standardising mechanical or wind-derived energy in terms of man-power, particularly as it may not be possible to eliminate variables such as the detailed structure of the gear and the nature of the bottom. Moreover, no division by the nature of power is valid, as the level of mechanisation of the fishing industry is often indicative only of the stage of development of the community concerned, the size of gear, and the standard of living, which in its turn is an important determining factor in the supply and cost of labour.

In the Colony of Singapore the use of mechanical power in the fishing industry has been discouraged by regulations in neighbouring territories which prohibit fishing but permit the purchase of fish from the indigenous fishermen. Development is therefore, largely restricted to powered fish-carriers, so that the gears of this territory provide a simple example for the consideration of classification by the power required for operation.

The following illustrates the power used in the more important gears :—

MAN-POWER UTILISED IN OPERATION.

1	2	3	5 to 7	12 to 18	18 to 25	25 to 30
Manual collection, rakes, spears, poisons, baited loop-fishing, handline, rod and line, long line (Johore Straits), cuttle-fish jig, filter nets, lift nets, dip nets, cast nets, push nets, Chinese drift net (*jaring hanyut*), Malay *selangat* net, *jaring tamban*, *jaring belanak*, troll line (from non-powered boat) and fishing stake (*belat*).	Spears, harpoons, poisons, filter nets, lift nets, cast nets, drive in gill nets, Malay drift net (*jaring hanyut*), Chinese *selangat* net, sunken gill and tangle nets, fishing stake (*belat*). Fishing stake (*kelong*)— Set barrier nets—	Hand-operated trawl	Beach seine (small)	Beach seine (large)	*Puhat payang* (lampara)	Drive in net, *Moro-ami* and Purse seine.

A single fisherman may also operate a number of fishing gears, for example, twelve to forty baited float lines (*pelontang*), ten to thirty baited crab lift nets or ten to thirty-five baited crab pots. The man-power required for the operation of portable fish traps varies with the size and number of such traps used.

Clearly, therefore, this principle does not afford an adequate basis for systematic study, reflecting as it does a number of features the most important of which are as follows :—

(1) *Size and Weight of Gear*, e.g., set barriers vary in size from those a few yards in length to structures over 800 fathoms long.

(2) *Mode of Operation*, e.g., gears which 'search' or employ scarer devices generally have high power requirements.

(3) *Base from which operated*, e.g., in villages remote from the fishing grounds additional man-power is required for propulsion of the boat and/or carriage of the gear. Moreover, the operation of a gear from a boat, e.g., spears and cast nets, may necessitate the use of a non-fishing assistant.

(4) *Mechanical Devices*, e.g., the presence of devices such as the Chinese windlass on *kelongs* or the use of a wheeled cart for transport of gear by land, reduces man-power requirements.

(5) *Financial Status of Operator*, e.g., the number of small gears, such as baited crab-pots, employed by a single fishermen is often determined by his financial status. In the case of larger gears, operators may increase the number of assistants in times of increased prosperity in order to lessen their individual work. This practice is particularly common on fishing stakes where monthly-paid labour is employed and is sufficiently organised to impose conditions upon the owner.

(6) *Human variability and behaviour*, e.g., the efficiency of the individual fisherman

is an important factor in determining the man-power required for the operation of fishing gear. The moro ami or drive-in net can be operated by 18 to 20 experienced operators whereas at least thirty less-skilled operators are necessary. These variable factors cannot be readily eliminated and as standardization is, therefore, impossible, it is clear that differences in man-power requirements do not necessarily constitute a significant factor.

5. The Constructional Design

It is important to differentiate between the materials of construction, the availability of which is often a determining factor of design, and the actual constructional design itself. For example, netting is used in a great number of gears but it cannot be considered a design in itself, being a meshed 'fabric' prepared from a variety of materials. Consideration of constructional design must, therefore, be approached from the specific aspect of the pattern of the gear. This raises immediate difficulties as there are methods of fishing in which no fishing gear is used, e.g., manual collection of fish. The equipment used in certain other methods can hardly be classified by any system based on constructional design, e.g., poisons, explosives and hunting with trained animals. These methods must, therefore, be omitted and the gears with a tangible design considered. In the first place, it is possible to divide constructional design in accordance with the major planes it utilises.

Gears can then be broadly grouped as follows :—

NUMBER OF PLANES OCCUPIED BY DESIGN*

ONE	TWO	THREE
Fish-smothering, snares, hooks, gorges, set barriers, jungle knives, spears, lift nets, drop nets, gill and tangle nets, snap nets, seines without bag, purse seines.	Spears, gorges, hooks, verandah nets, jumping platforms.	Rakes, spears, jigs, filter nets and stakes, aerial traps, lift nets, cast nets, drive in bag nets, portable fish traps, fishing seines with bags, dredges, trawls, lamparas.

It is clear that certain gears, which are grouped together as a result of similarity in design, are operated in entirely different ways. For example, single plane designs executed in closely woven or meshed fabric include fish-smothering, lift nets, drop nets, entangling nets, seines without bag and purse seines, although the modes of operation and detailed construction vary widely. Moreover, spears and hooks are now separated in accordance with the complexity of their design, purse seines are grouped with entangling nets and set barriers, and seines are divided by the presence or absence of a bag. Further sub-division by constructional design is not, therefore, justified and as a basis for classification this property must be rejected.

6. The Materials of Construction

Materials used in the construction of fishing gear are extremely varied, human ingenuity having utilised the materials which were most suitable in respect of their nature, availability and accessibility. This would suggest that, unless the material is a determining factor in the design and method of operation, it is likely to prove too variable a feature for the purpose of systematic classification. In the study of the preceding principle it was pointed out that in certain fishing methods no equipment is used and this objection is equally valid in this case. Moreover, fishing gears may consist of more than one material in which case it becomes necessary to classify them by the material which is used in the operative feature of the gear.

Classification by materials of construction can, therefore, be summarised as follows :—

Material of Construction	Gears	Remarks
1. *Inorganic Materials* 1.1 Flint and Stone.	Spears, gorges, hooks, set barriers.	Generally primitive gears employed by Palaeolithic and Neolithic man. Set barriers of stone are still employed and Davis (1927) quotes several in use in the United Kingdom.

**Note*:—For the purpose of this consideration three major planes are recognised, intersecting each other at right angles.

Material of Construction	Gears	Remarks
1.2 Mother of Pearl.	Gorges and hooks.	
1.3 Metals.	Spears, rakes, knives, arrows, snares, loop-fishing, gorges, hooks, jigs, gaffs, portable fish traps, wire-netting fishing stakes, oyster dredges.	A great variety of metals have been used in the construction of fishing gear and there are even records of hooks of gold. (Radcliffe, 1926.) Portable fish traps and fishing stakes *belats*) in Singapore are being constructed with wire-netting enclosures thus reducing labour costs.
2. *Organic Materials*		
2.1 Natural wood and other plant materials (excluding fibres).	Plunge basket, rakes, spears, arrows, darts, gorges, hooks, set barriers, filter devices, portable fish traps, fishing stakes, anchovy boards and jumping platform traps, snap nets.	A wide range of woods are utilised, bamboos, rattans and palms being of particular importance in Malaya. The use of laced, banyan bark strips in the snap net reflects the primitive status of the aborigines concerned.
2.2 Fibres.	Snares, loop-fishing, set barriers, filter nets, stake nets, portable fish traps (lobster pots), set stake nets, cast nets, bag nets, verandah nets, all entangling or gill nets, seines, trawls, purse seines, dredges, lamparas.	Fibres include rami, cotton, linen, hemp, sunn (san hemp), silk, gut, spiders' web, and nylon (synthetic). This heterogenous group includes all gears utilising fibre netting. Fibres also play an important part in hook and line fishing but are subsidiary to the operative feature —the hook. A web spun by spiders into a prepared frame is recorded as in use by Papuans as a dip net, holding fish of up to one pound in weight. (Radcliffe, 1926)
2.3 Other Animal Products. 2.31 Chitin.	Hooks.	A natural fish hook prepared from the thick upper joint of the insect *Eurycantha latro*, is recorded from Good-enough Island, New Guinea. (Radcliffe, 1926)
2.32 Horn, turtle-shell, bone and ivory.	Spears, harpoons, gorges, hooks.	These materials were used by prehistoric man in some of the earliest fishing gear recorded. Their use at present is limited to primitive and isolated communities.

It is obvious that the great variation in the usage of materials for the manufacture of fishing gear renders them invalid as a basis for classification. It is particularly interesting to note that in this Colony the manufacture of portable fish traps from woven rattan has been discontinued within the last few years, rattan as a material of construction being replaced entirely by wire-netting. This reduces labour charges which are heavy. The original shape, which was clearly determined by the method of weaving, has been retained.

7. The Location of Operation

Hornell (1925 and 1938) in his papers on the fishing methods of the Madras Presidency considered it necessary to adopt a broad classification based on the location of operations, i.e., marine, estuarine and inland. The seasonal nature of the inland fisheries and the remarkable development of estuarine lagoons and creeks in that area support this conclusion. However, in any consideration of classification by location of operation it is

necessary to expand this classification to accommodate localities which have a distinct ecological significance.

A classification of fishing methods by the area of location of operation would, therefore, be as follows :—

Location of Operation	Type of Fishing Methods Employed	Remarks
1. *Fresh-water Fisheries*		
1.1 Lakes.	Artificial fish holes, spears, arrows, poisons, explosives, snares, gorges, hooks, portable fish traps, fishing stakes, cast nets, drop nets, dip nets, gill nets and seines.	This list can only be offered as provisional, as the literature on lake fisheries to which the author had access was limited.
1.2 River Systems.	Artificial fish hooks, plunge baskets, spears, arrows, darts, poisons, noxious fluids, explosives, snares, gorges, hooks, set barriers, fish fences with entrapments, portable fish traps, collapsing bag nets, lift nets, scoop and dip nets, drop nets, cast nets, aerial traps, gill nets, seines, drag fences.	The variety of gears operated in river systems is well typified by those employed in Burma, where the river and delta fisheries are of major importance.
1.3 Marshes and Padi-fields.	Plunge baskets, jungle knives, spears, fish-smothering, snares, gorges and baited springs, rod and line, portable fish traps, cast nets, scoop and dip nets.	The restricted nature of the fishing is a determining factor in the type of gear that can be utilised.
2. *Estuarine Fisheries*	Manual collection, artificial fish holes, rakes, spears, poisons, explosives, snares, gorges, hooks, set barriers, filter nets and stake nets, portable fish traps, fishing stakes, lift nets, drop nets, push nets, cast nets aerial traps, gill and tangle nets, drive in gill nets, seines and trawls.	The rich estuarine fisheries of South-East Asia are usually exploited by every means which the nature of the area and fisheries legislation will permit.
3. *Marine Fisheries*		
3.1 Littoral.	Manual collection, rakes, spears etc., hooks, gorges, set barriers, portable fish traps, fishing stakes, lift nets, cast nets, drop nets, scoop nets, push nets, some gill nets, (e.g. *jaring puput*), seines, snap nets.	The accessibility of the littoral fisheries renders them of considerable importance in South-East Asia.
3.2 Coastal or inshore.	Octopus pots, shell collection, spears and harpoons, poison-bait, explosives, trained animals, loop-fishing, hooks, filter devices (in areas with marked tidal stream) portable fish traps, fishing stakes, lift nets, verandah nets, gill nets, tangle nets, trammel nets, seines, dredges, trawls, purse seines, lamparas.	This includes those areas in the comparatively shallow waters near the coast. Coral reef areas have been excluded in view of their very special nature.
3.3 Coral Reef.	Manual collection, spears, harpoons, spear guns, poisons, explosives, hooks, portable fish traps, fishing stakes, cast nets, drive in bag nets, drive in gill nets, seine nets.	The nature of coral necessitates a modification of fishing methods with a resultant increased requirement in both man-power and skill. In consequence the use of explosives, which requires little skill, has grown to the detriment of the resource.
3.4 Pelagic or offshore.	Harpoons, explosives, hunting by animals, loop-fishing, hooks, lift nets, gill nets, seines, trawls, purse seines, lamparas	The pelagic fisheries occupy the upper layers of the sea down to about 100 fathoms. They overflow into the coastal and estuarine areas, and pelagic fish may be taken in typically bottom gears, e.g., herring in trawls.
3.5 Abyssal and bathypelagic.	Hooks, dredges, trawls, grabs.	This includes the slope to and sea floor in the abysses and the intermediate layers of the open sea from, say, 100 fathoms to near the bottom. The resources of these areas are not normally exploited by fishermen although there is a special long line fishery at the Azores for the bathy-pelagic scabbard fish (Irvine, 1947).

The objections to employing the location of operations as a method of classifying fishing methods are obvious and, even if marked differences in such methods could be demonstrated, the absence of limiting boundaries would provide a major obstacle to the use of this principle. For example, pelagic fish enter the inshore or coastal areas and the wide variation in salinity in the estuaries enables some fresh-water and marine fish to enter this area.

Location of operations, therefore, provides no basis for a systematic classification of fishing methods although it is clear that certain areas are more suitable for specific types of gear, e.g., filter devices in estuarine areas, and that, in a few cases, gears may be restricted to one particular locality, e.g., fish-smothering.

8. The Species Captured.

In South East Asia information regarding the catch composition of the various fishing methods is often fragmentary and the collection of detailed knowledge is complicated by the large number of species concerned. This presents an immediate obstacle to the use of this principle as a basis for classification. Moreover, certain methods exploit the entire fishery resources of the area in which they are operated, being virtually indiscriminate in their action, e.g., manual collection, poisons, set barriers, beach seines. In the Colony of Singapore very few gears are specific in their action, a notable exception being the two-man lift net which is solely operated to capture mullets (*Mugil* spp.). On the other hand, there are important fisheries in which the various gears utilised show little similarity, other than in the composition of the catch. For example, *Scomberomorus* spp. and *Chirocentrus dorab* (Forskall) are taken both by the floated line (*pelontang*) and a drift net (*jaring hanyut*). These gears have nothing in common in structure, method of operation or even capital cost. A better known example is to be found in the tuna fisheries which are exploited by purse seines, trolling lines and set pound nets. Clearly this diversity is the result of human ingenuity, capture of the fish being achieved by exploiting any well-established behaviourism.

DISCUSSION

It has been shown that of the varying principles upon which a detailed classification can be based, only the precise manner in which capture is effected provides a satisfactory basis.

Briefly there are certain principles which can be immediately dismissed from consideration as a basis for classification. For example, the materials of construction are of importance only in so far as their properties permit their use in capture operations, and they can be readily replaced by different materials with similar or more suitable properties. Furthermore, the location of operations and the species captured represent factors for which fishing methods have been devised, and they act as limiting factors to the number of methods which can be used rather than permitting distinction between such methods. Constructional design is entirely subservient to the way in which capture is achieved, and any detailed study of design inevitably involves consideration of this.

On the other hand, the power required for the operation of fishing gear is of great importance from the statistical and administrative aspects of the fishing industry. It has, however, been emphasized that the power required is dependent upon a number of factors and that the efficiency of the individual fisherman is a variable factor which, cannot be simply eliminated. It is not proposed therefore, to utilise the power requirement of the fishing methods in construction of a classification but it is clear that the size of the gear should be used as a minor identifying character.

The method by which the fish are brought into relationship with the gear is primarily a question of the distribution of the fish concerned and the method by which this distribution is exploited. Similarly, the actual method of operation of the gear is the preliminary step whereby the gear is brought into relationship with the fish with a view to employing a precise method of capture.

In consequence, the precise manner in which capture is effected has been utilised as a basis for the preparation of a classification which is included as an Appendix. For the minor details of the classification some use has been made of the method in which the fish are brought into relationship with the gear, the method by which the gear is operated and the dimensions of the gear, but these have been subordinated to the precise method of capture. In the case of those gears, in which this property varies in accordance with the mode of operation, the method for which the gear was designed or is principally employed has been used for determining its position in the classification. Should a gear be a true dual purpose implement, that is, if its normal usage includes more than one precise method of capture, it may be necessary to establish additional groups in the classification. For example, the *kola vala* and *kandadi vala* of Madras appear from Hornell's description to be equally concerned with the gilling of small fish and the entanglement of larger ones. Should this be indeed the fact it would be desirable to establish a new group, ' Gill-Tangle ' nets.

Reference to the Appendix will show that there are apparent anomalies which require further consideration. For example, complete barriers may be simple structures in which the fish are stranded when the water recedes, or may utilise traps or other devices to secure the fish. In the latter case it would appear that the barrier might equally well be classed elsewhere, depending upon the nature of the trap or device. The fish are restrained by the barrier and that the method of securing the fish is subsidiary to this. On the other hand, if a trap is used in a natural barrier, or barrier which was constructed for some other purpose, e.g., a bund of a paddy-field, the fish are not the subject of deliberate restraint until they enter the trap. In the consideration of barriers it is important to differentiate between guiding barriers and set barriers. Clearly the latter are devices which, by simple physical obstruction, prevent the escape of fish from a particular natural area which they entered voluntarily. Guiding barriers, on the other hand, are so designed to direct the voluntary movements of fish into a desired area.

The use of non-return devices in certain filter nets would suggest that the gears in question should be grouped with traps containing similar structures. In fact, the net operates by screening out the catch and the non-return devices are only added to boost the retaining action of the current where it is weak or the anticipated catch consists of strongly swimming forms.

The division of Gape Nets by their position vis-a-vis the current is not justifiable except on the grounds that it provides significant information as to the effective length of the fishing day. Certain of the fixed filter nets are, however, operated in batteries connected by a guiding barrier in such a way as to ensure that adjacent gears face in opposite directions. In this case each gear is a fixed individual unit which operates only on one tide, and its productivity is accordingly limited although it must be admitted that its effectiveness is substantially increased by the use of the guiding barriers. Further sub-division of these nets can be achieved, therefore, by their use in conjunction with such barriers or by the use of non-return valves, both of which may lead to an increase in productivity.

Aerial traps may include the use of a horizontal trammel net, e.g., the verandah net, or bushes to trap fish leaping over a suspected barrier. These structures cannot be considered as principally entangling devices, as they are more concerned with retention of the catch than with its actual capture. In certain districts, the push net bears a long bag into which the catch is swept by the movement of the net through the water—an obvious similarity to certain of the investing gears—but in most cases the catch is not secured until the net is raised and this suggests that the similarity is not of fundamental significance.

In conclusion it is clear from this classification that there is also a need for a standard nomenclature of fishing gear—a nomenclature which could be devised by the expansion of this classification to its logical conclusion. Such an undertaking, however, would require a more detailed knowledge of the fishing gear of this area than is at present available, and from a study of the existing work on the subject it is clear that in many cases the existing descriptions are inadequate or are lacking in details of vital importance.

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APPENDIX

AN OUTLINE CLASSIFICATION OF FISHING GEAR AND METHODS

Division 1

INDIVIDUAL OR SPECIFIC

Fishing methods in which individual fish are the subject of the capture operation.

1.1 Manual Collection

All methods in which the catch is secured by seizing or grasping with the hands.

1.11 **Simple.**—Manual collection in which no concentration of the resource is undertaken.

1.111 *Without restraining equipment*, e.g., shore collection : trochus, green snail and pearl collection.

1.112 *With restraining equipment*, e.g., plunge baskets, jungle knives (used to strike not impale), eel spears (Hawaiian spears in which the operative principle is not piercing but jamming between tooth-like prongs).

1.12 **Concentrative.**—Manual collection in which the resource is concentrated by various means.

1.121 *Refuge Devices.*—Devices which concentrate fish by providing a shelter or refuge from which the catch is removed, e.g., artificial fish-holes, octopus pots.

1.122 *Raking Devices.*—Comb-like devices which facilitate subsequent manual collection, e.g., oyster, mussel and cockle rakes, crab hook (Singapore and Thailand).

1.123 *Scarer Devices.*—Devices which are employed to drive or concentrate fish at a specific point at which the operator is situated, e.g., scare-line or vela vala (Madras).

1.2 Nooses

All devices whereby fish are secured in a simple or complex noose.

1.21 **Snaring.**—A noose is slipped over the fish to be secured and is drawn tight, e.g., shark-fishing in Polynesia (Hornell, 1950), *jai* (Malaya).

1.22 **Loop-fishing.**—The fish is attracted to a noose by means of a bait or a lure and is secured by drawing the noose tight on to the upper jaw of the fish. The method is restricted to the gar-fish (Belone sp.) and may be operated in conjunction with a kite, e.g., in Singapore, parts of Indonesia, and in Melanesia with a looped tassel of spiders' web.

1.23 **Tassel-fishing.**—This is an extension of loop-fishing in which the noose is replaced by a tuft or tassel of fibres, the individual teeth of certain fish being secured by their penetration into the fibres to form a multiple system of loops. This method may be used in conjunction with bait, e.g., rəo pla tong (Thailand) (Swaing, 1950) or the tassel itself may operate as a lure, e.g., eel fishing with wool (England).

1.3 Bait-Holders

Devices consisting of a small rod, tapering to a point at each end and secured in the centre by a line The gorge is baited and fish taking the bait are secured, the gorge resisting withdrawal.

1.31 **Gorges.**—Rigid bait-holders, e.g., Palaeolithic man in Europe and America.

1.32 **Baited Spring.**—Flexible bait-holders set by bending the ends together and securing them in the bait, e.g., barra, kai-barsa and datia (India).

1.4 Hunting Animals

All methods in which trained animals are used for the capture of fish.

1.41 Cormorants.— e.g. China & Japan.

1.42 Otters.— e.g. Europe, Yangtze Valley (China), Sunderbans (India).

1.43 **Sucker-fish** (*Echeneis* sp.).—This method had a wide distribution at one time but it is now mainly restricted to Zanzibar, and the Great Barrier Reefs, Australia. (Hornell, 1950).

1.44 **Dogs.**—The ' orang laut ' of South Johore, Malaya, are reported to hunt crabs with dogs. (Williams Hunt—Personal communication, 1951).

1.5 Sharp Projectiles

All methods in which the catch is secured by impaling a straight, pointed implement.

1.51 **Lances.**—Thrusting implements with a long shaft and a pointed, unbarbed head.

1.511	*Multident,*	e.g. konch (Bengal)
1.512	*Unident,*	e.g. tirok (Malaya), manda (Pearson, 1922) (Ceylon)
1.513	*Bident,*	e.g. manda (Ceylon)
1.514	*Trident,*	e.g. Tilapia lance (Singapore)

1.52 **Spears.**—Thrusting implements with a long shaft and a pointed, barbed head.

1.521	*Multident,*	e.g. mandal (Ceylon)
1.522	*Unident,*	e.g. tempuling (Malaya)
1.523	*Bident,*	e.g. dukathi (India)
1.524	*Trident,*	e.g. serampang (Singapore)
1.525	*Cinqident,*	e.g. serampang sotong (Singapore)

Further sub-division can be achieved by use of the number and nature of the barbs, e.g., uni or bi-barbed, hinged or otherwise. Spears may be thrown in which case a line is used to retain them, but these are to be distinguished from harpoons.

1.53 **Harpoons.**—Spear-like instruments with a detachable, barbed head.

1.531	*Multident,*	e.g. juti or jutiya or konch (India)
1.532	*Unident,*	e.g. julir (Malaya)
1.533	*Bident,*	e.g. manda (Ceylon)
1.534	*Trident.*	

1.54 **Pointed Missiles.**—Pointed missiles propelled from :—

1.541	*Blow-guns,*	e.g. thumbithan (Malabar)
1.542	*Bows,*	e.g. thettal (Malabar)
1.543	*Cross-bows,*	e.g. parangi pathu (South India)
1.544	*Spear-guns,*	e.g. Philippines.

1.6 Hooks

All methods in which capture is effected by the penetration of a curved point.

1.61 **Gaffs.**—A hook device, used without line to capture and land fish, e.g., sickle (Madras), malu kottanakaduwa (Ceylon). It does not include the use of instruments for securing fish after capture by other methods, e.g., salmon gaff, aulun biliya (Ceylon).

1.62 **Hook and Line.**—A hook device operated in conjunction with a line by which fish secured on the hook can be hauled to the operator.

1.621 **' Foul Hooking '.**—Methods employed whereby the hook penetrates a part of the fish not being the mouth.

1.621.1 *Simple.*—Devices in which a simple hook effects capture, e.g., taung-gyin (Burma), jota (Bengal), rawei tidak umpan (Malaya), bed rao pla kaben (Thailand).

1.621.2 *Complex.*—Devices in which a compound hook or jug is employed, e.g., chandit (Malaya), kahawa (Ceylon).

1.622 *' Clean Hooking '.*—Methods employed whereby the hook penetrates the mouth of the fish.

1.622.1 *Troll-lines.*—The hook is drawn through the water or 'trolled', usually from a boat, e.g., troll lines and surf-whiffing.

1.622.2 *Angling.*—Devices which consist of a limited number of hooks (usually not more than three) which are generally attached at the distal end of a vertical line. The gear is operated in a restricted locality and is not trolled, e.g.,

1.622.21 Rod and line

1.622.22 Hand line

1.622.23 Floated line.

1.622.3 *Trap Lines.*—Devices consisting of a single hook and line which are set to operate automatically, the fish being secured by releasing a spring device, e.g., joran taut and kiding (Malaya, also Bengal).

1.622.4 *Long Lines.*—Devices which consist of a number of hooks attached along the length of a horizontal main line by snoods, e.g., dab lines, long lines.

Division 2.

INDISCRIMINATE OR DIFFUSE

Fishing methods which are usually indiscriminate or diffuse in action affecting all fish within the area of operation.

2.1 Poisons

All methods in which capture is achieved by the use of a toxic substance which poisons or stupefies the fish.

2.11 **Indiscriminate or Diffuse.**—Use of toxic substances by poisoning the water, e.g., *Derris* sp. (Malaya), *Tephrosia* sp. (Africa).

2.12 **Specific.**—The use of toxic substances through poison bait or poisoned projectile, e.g., poison bait (Singapore), poison whaling with harpoon (Ainus, Aleuts. etc.) (Govt. St. Settles., 1896.)

2.2 Suffocation

This includes a single method practised in waters of low oxygen-content, in which capture is effected by denying air-breathing fish access to that element.

2.21 **Smothering,** e.g., fish smothering (Burma)

2.3 Explosives

All methods in which explosives are used to stun or kill fish. It does not include the use of explosives to propel missiles.

2.31 **Indiscriminate,** e.g., ' dynamiting '.

2.32 **Specific,** e.g., explosive whale harpoons.

Division 3.

MULTIPLE OR COLLECTIVE

Fishing methods in which generally a group or association of fish are the subject of the capture operation.

3.1 Entrapping Structures

All methods of fish capture achieved by use of an enclosure which affords free access but from which escape is hindered or prevented in a variety of ways, the precise method being utilised for subdivision of the group.

3.11 **Simple Enclosures.**—A device which, by simple physical obstruction, prevents the escape of fish from a certain natural area which they entered voluntarily.

3.111 *Complete barriers.*—Permanent or semi-permanent structures of stone, earth, wood or netting erected to block the escape of fish from an area. The water may escape through the structure or be removed by baling. Such barriers may be submerged at times of flooding, tidal or otherwise, or may have an entrance which dries out before the main area of the enclosure, e.g., in South Devon, Wales, Queensland, America (Davis, 1927), Bengal (Hornell, 1950), Madras (Hornell, 1925 & 1938), Burma.

3.112 *Complete barriers with entrance.*—Complete barriers which contain an entrance to facilitate the movement of fish into the area. The entrance is closed by the operator thus completing capture. These traps may be operated in connection with ground bait and/or bush shelters, e.g., in Cameroons (Hornell, 1930), Burma.

3.113 *Set barriers.*—Structures of netting, screens of rattan, brushwood etc., which are set so as to cut off an area which later dries out. These barriers are typically employed in tidal waters where a large expanse is uncovered at low-water. They require to be set for each operation, e.g., block (Thailand), ampang (Malaya), bawun and paik-bawun (Burma), stop nets (Thames Estuary—Davis, 1927).

3.114 *Tidal-operated barriers.*—Structures of netting or other materials which allow the passage of the fish on the flood-tide but which prevent escape on the ebb-tide through a device operated by the tidal stream itself, e.g., baulk nets (Morecambe Bay, U.K.), roa nets (Davis, 1927).

3.12 **Screening Devices.**—Structures set in moving water which screen or filter out the catch, the force of the current ensuring its retention. These devices may be used with guiding barriers and, where the current is not strong or the anticipated catch consists of strongly swimming species, non-return devices may be used to increase productivity.

3.121 *Stream Nets.*—Filter devices similar to ' tidal-operated barrier ' nets which are not, however, set to enclose an area completely but form a shallow horizontal bagging in which fish are trapped, exit being prevented by the force of the current, e.g., stream nets (England—Davis, 1927).

3.122 *Gape Nets.*—Filter devices with a distinct mouth into which fish are carried by a moving current.

3.122.1 *Static.*—Gape nets fixed in respect of their direction of operation, i.e., they remain in the same position at all times of the tide, e.g., ambai (Malaya and Thailand), valu vala (Madras), bandu dela (Ceylon), dashiami (Japan), hose nets (England), kyapazat (Burma).

3.122.2 *Oscillatory.*—Gape nets which are free to swing in the current and thus can fish on both the ebb-and flood-tides.

3.122.21 *Swing Nets.*—Gape nets which are buoyed and anchored in such a way as to facilitate change in direction in response to changes in the direction of the current, e.g., swing net (England), ambai (Thailand), pompang (Malaya), pinledamin (Burma).

3.122.22 *Stow Nets.*—Gape nets which are suspended from an anchored boat or raft, e.g., stow net and double trawl (England), paikganan (Burma).

3.123 *Screen Nets.*—Filter nets which consist of an inclined screen on to which fish are carried and stranded by a current of water.

3.1231 *Staked.*—Screen nets fixed in respect of their direction of operation, usually employed with a guiding barrier, e.g., jermal (Malaya), various fish fences with sloping platforms (Burma).

3.1232 *Pendulous.*—Screen nets which are lowered from a boat or raft, e.g., pazunbaung and hle-damin (Burma).

3.13 **Structural Non-Return Devices.**—Structures which permit the free and voluntary entrance of fish but which hinder or prevent its escape by a structural non-return device.

3.131 *Tubular traps.*—Structures tubular in form, the diameter of which is carefully adjusted to approximate closely to the average girth of fish to be caught.

3.131.1 *Smooth.*—Tubular traps in which fish enter the trap and are held only by the closeness of the fit, e.g., salmon putcher (England), murrel trap (India)—Hornell, 1925 & 1938), uringate (Africa), also in Philippine Islands Fiji, Borneo.

3.131.2 *Thorn-lined.*—Tubular traps in which fish enter the trap and are held by the closeness of the fit in conjunction with a thorn lining, e.g., in Fiji and Bismarck Archipelago.

3.132 *Funnel Traps.*—Structures in which entrance is easy but from which exit is rendered difficult by a non-return device in the form of a funnel. They also include traps in which fish enter a large chamber through a narrow aperture at the end of converging walls, exit being rendered difficult by the fact that the walls on the inside of the trap diverge from the aperture.

3.132.1 *Portable Traps.*—Rigid funnel traps usually small in size which are movable and are complete in themselves, e.g., zale and bon-pin (Burma), bubu (Malaya), bubo (Philippines), nassa (Italy), lobster pots (England), susa (Fiji), unagi kago (Japan) and throughout South-East Asia.

3.132.2 *Set or Pound Traps.*—Non-rigid funnel traps usually constructed of netting which are set to exploit seasonal fisheries and can be subsequently removed and set elsewhere, e.g., fishing pounds (Mediterranean), daibe ami (Japan), keddle nets (England), seraku valai (Ceylon).

3.132.3 *Palisade Traps.*—Rigid funnel traps which are erected as semi-permanent structures and which intercept the catch by means of guiding stakes or leads, e.g, belat and kelong (Malaya), poh and poh lemut (Thailand), sero (Indonesia), kandi and akulwetiya (Ceylon), bashuwin and lutgyi (Burma), sardine weir (Canada).

3.133 *Mechanical Traps.*—Structures which permit the free and voluntary entrance of fish but which prevent its escape by means of a shutter or spring-trap operated by the action of the fish.

3.133.1 *Weighted Shutter.*—Mechanical traps in which a weighted shutter falls and imprisons the catch, e.g., tok (Burma), balboob (Philippines).

3.133.2 *Spring Shutter.*—Mechanical traps in which a shutter activated by a spring, usually made of bamboo, imprisons the catch, e.g., in Malayasia.

3.14 **Aerial Traps.**—Traps exploiting the habit of certain fish which leave the water when confronted by an obstacle.

3.141 *Pitfall traps.*—Entrapments which consist of complete barrier with a pit dug near each end, into which some fish fall in trying to make their way round overland, e.g., nga-dwin-(Burma).

3.142 *Jumping Traps.*—Entrapments which exploit the habit of certain fish in jumping over an obstacle.

3.142.1 *Without scaring.*—Complete barriers with a platform usually of netting or bamboo on to which fish fall in trying to leap the barrier, e.g., kon-sin and kon-paik (Burma), kattu valai (India) and in Malaya.

3.142.2 *With scaring.*—Methods in which certain species are constrained to jump a trapped obstacle by the use of scarer devices.

3.142.21 *Verandah nets.*—Encircling nets to the outer side of which is attached a floated horizontal trammel net, e.g., tiweek (Palestine) and in Mauritius (Hornell, 1950).

3.142.22 *Boat & Raft traps.*—Boats and rafts into which the fish are constrained to leap by the use of scarer devices, e.g., chali (Bengal), changodam (South India), anchovy boards (Hongkong), tazaung (Burma), catch boats (Thailand), seriat (Malaya), also in Malta, China, Africa & Malayasia.

3.15 **Lift & Drop Entrapments.**—Structures, usually consisting of a sheet of meshed fabric, which are raised or lowered to trap fish above or below the gear.

3.151 *Lift Nets.*—Structures which are raised to trap fish passing over or lying above them.

3.151.1 *Vertical.*—Lift nets which are raised vertically, an oblique or sideways movement being of no significance in the capture operation.

3.151.11 *Baited.*—Vertically operating lift nets which are baited. (This does not include the use of ground-bait to attract the fish).

315.111.1 *Crab-traps* in which fabric entangles the catch, e.g., bintur (Malaya), kakula watte (Ceylon).

315.111.2 *Fish-traps* in which fabric encloses, e.g., fukuro ami or file-fish nets (Japan), hoop nets (England), etc.

3.151.12 *Unbaited.*—Vertically operating lift nets which are not baited, but to which the fish may be brought into relationship with the gear by scattering ground bait or scaring etc., e.g., ya-gwin (Burma), endi balai (Madras), pukat tangkul & tangkul (Malaya), cheena vala (Madras), shiso hari ami (Japan), atoli dela (Ceylon) and in Hongkong.

3.151.2 *Oblique.*—Lift nets which are drawn or pushed obliquely before hauling, the oblique movement being of significance in the capture operation.

3.151.21 *Scoop & Dip nets.*—Lift nets which are pushed through the water in a complex scooping movement, before raising, e.g., athangowa (Ceylon), dawkat (Burma), arippu vala (Madras), tama ami (Japan) and world-wide distribution.

3.151.22 *Push nets.*—Lift nets which are pushed along the bottom in an oblique collecting movement before raising.

3.151.221 *With scaring*, e.g., pala delah (Ceylon).

3.151.222 *Without scaring*, e.g., push & thrust nets (Malaya, Burma, Thailand, Indonesia, etc.).

3.151.23 *Screen nets.*—Lift nets which are drawn through the water obliquely in a simple linear movement before hauling, e.g., boke ami & yatsude ami (Japan), pukat sudu (Malaya), etc.

3.152 *Falling Nets.*—Structures which are lowered or allowed to fall, thus trapping fish passing or lying below them.

3.152.1 *Cast nets.*—Conical or bell-shaped nets with a weighted periphery, which are thrown to cover an area, and which trap fish lying below them as they fall to the bottom or as the weighted periphery closes.

3.152.11 *Stringed*
3.152.12 *Stringless.* } Distribution throughout the world.

3.152.2 *Drop nets.*—Nets which are dropped or allowed to fall without a preceding casting movement, e.g., metkun (Burma), chochin ami or lantern net (Japan), tereben (Lake Chad), chak-jal (India).

3.2 Entangling structures

Structures of meshed fabric in which the fish jams or entangles itself in the actual fabric.

3.21 **Gill nets.**—Entangling structures in which the fish becomes tightly jammed or otherwise trapped in an individual mesh. This includes a great number of gears and it is suggested that sub-division be made by approximate mesh size. Further sub-division can then be made by the depth of the net in meshes which reflects the conditions under which the net is operated, whether it is floating or sunken, anchored or free and as to the method by which the fish are brought into relationship with the gear. A classification of all the gill nets in this area is clearly beyond the scope of this paper even if it were possible from the limited information available, but to illustrate the method the gill nets of the Colony of Singapore are classified below :—

3.211 *½ inch Bar.*

3.211.1 *Floating.*

3.211.11 206 *meshes deep.*—Jaring tamban—a floating drift net used for the capture of tamban.

3.211.12 250 *meshes deep.*—Jaring tamban—a drift or anchored gill net, which, is employed for the capture of bait fish (In this Colony the net is used only as an anchored gill net, but its use with a cocoanut-leaf lure from a drifting boat is recorded from Penang, Govt. St. Settles., 1896).

3.211.2 *Sunken*—nil.

3.212 *One inch bar.*

3.212.1 *Floating.*

3.212.11 19 *meshes deep.*—Jaring selangat (Chinese)—an anchored, floating gill net into which fish are driven by scaring.

3.212.12 22½ *meshes deep.*—Jaring puput—a floating gill net (actual bar $\frac{5}{6}$ inches), the principal catch being the half-beak. (Hemirhampidae).

3.212.13 30 *meshes deep.*—Jaring belanak—a floating drift net, the principal catch being belanak (Mugil spp.).

3.212.14 99 *meshes deep.*—Jaring selangat (Malay),—a floating drift net, the principal catch being kapas (Gerridae) and kerong (Theraponidae).

3.212.2 *Sunken.*

321.221 23 *meshes deep.*—Jaring tenggelam—a sunken, set net.

3.213 $1\frac{3}{16}$ *inch bar.*

3.213.1 *Floating.*

3.213.11 24 *meshes deep.*—Jaring karang—an anchored, floating gill net into which fish are driven by scaring.

3.213.2 *Sunken.*—nil.

3.214 1½ *inch bar.*

3.214.1 *Floating.*

321.411 105 *meshes deep.*—Jaring hanyut—a floating drift net of 1½ or $1\frac{3}{8}$ inch bar, utilised in the parang (*Chirocentrus dorab*) and tenggiri (*Scombermorus* sp.) fisheries.

3.214.2 *Sunken.*—nil.

3.22 *Tangle Nets.*—Entangling structures in which the fish becomes entangled in several meshes of the fabric, e.g., jaring ketam (Malaya) ; sashi ami (Japan); crab or brat nets (England). Possibly the kola vala and kandadi vala (Madras), which are said to gill small and entangle large fish, should be included here, but their position must be determined on the relative importance of each method. Should productivity by both methods be similar, a new sub-head ' tangling gill nets ' will be necessary.

3.23 *Trammel Nets.*—Entangling structures which consist of an inner, loosely-hung sheet of small-mesh netting with two outer ' armourings ' of larger mesh. Fish striking the net pass through the armouring, forming a bag of the smaller lint which is constricted by the mesh of the further armouring, e.g., in Europe.

3.3 Engulfing Structures

Structures into which fish enter voluntarily or are driven as the result of scaring, the mouth or entrance to which is then closed.

3.31 **Closing Pouch Nets.**—Bag-shaped or similar receptacles into which fish enter voluntarily, the entrance or mouth of the bag then being closed or raised to prevent escape.

331.1 *Pendulous.*—Closing pouch nets which are suspended from a boat or other structure, e.g., shangla-jal and kharki-jal (India).

3.312 *Set.*—Closing pouch nets which are set on the bottom, the head-line usually being floated to the surface.

3.312.1 *Complete Bag*, e.g., tatta (Burma), chavittu valla (Madras).

3.312.2 *Incomplete Bag*, e.g., sankakugata oshikiami or triangular large set net (Japan).

3.32 **Drive-in Nets.**—Closing pouch nets into which fish are driven by scarer devices, the mouth of the bag then being closed or raised to prevent escape, e.g., paik-ta-se (Burma), oikomi ami (Japan), muro ami (Philippines), moro ami (Singapore & Indonesia).

3.4 Investing Structures

Structures which are dragged or hauled through the water, investing or enclosing any fish which are encountered. It also includes those gears which are set round a shoal of fish, thus enclosing it, capture being accomplished subsequently by pursing the bottom of the net, or by the use of subsidiary fishing gear.

3.41 **Snap Nets.**—Hinged or folding nets which are operated by snapping shut, thus investing any fish lying between the wings, e.g., Arnhem Land.

3.42 **Seines.**—Structures consisting of netting or similar material, which are set to enclose or partially enclose an area of water and through which the net is dragged to the shore or a boat.

3.421 *Drag Seines.*—Seines, consisting of a wall of netting, which may contain a bag but which are not extended by the use of long wings or warps, and are not set to encircle an area, e.g., gyan-taik, paik-chido (Burma), pond seines (Carp ponds, Malaya), ligkop (Philippines), pukat kisa (Malaya), vadi vala and tellikanni vala (Madras), etc.

3.422 *Haul Seines.*—Seines consisting of a wall of netting, with a bag or bags, modified by long wings and/or warps—

3.422.1 *Beach Seines.*—Haul seines specifically designed for use in shallow water, e.g., pukat tarek (Malaya), hiki ami (Japan), rampani seine (Madras), maha dela (Ceylon).

3.422.2 *Boat Seines.*—Haul seines specially designed for use in deep water.

3.422.21 *Floating*, e.g., vakku vala & odan vala (Madras), katumaran dela (Ceylon) etc.

3.422.22 *Sunken*, e.g., pukat payang (Malaya), Chinese-Danish seine and payang besar (Thailand), lamparas & Danish seines.

3.423 *Encircling Seines.*—Seines consisting of a wall of netting which is set to encircle and restrain a shoal.

3.423.1 *Hold.*—Encircling seines in which the catch is held in the net, being removed by subsidiary methods, e.g., large yellow croaker seine (Hongkong), Cornish pilchard seine (England).

3.423.2 *Purse.*—Encircling seines in which the catch is secured by pursing the foot-line, thus completing the enclosure. The net is then hauled and the catch removed directly, e.g., purse seines, ringnets, etc. (India, Thailand, Malaya, Hongkong, China, Japan).

3.43 **Bag Nets.**—Investing structures, sub-conical or bag-like in shape which are drawn through the water and which engulf the fish that are encountered. They differ from seines, in-so-much as they do not enclose an area but rather work it.

3.431 *Dredges.*—Engulfing bag nets which have a rigid lower boundary to the mouth, e.g., oyster dredge and shank nets (England), sokoribune (Japan), tanggok trepang (Kedah, Malaya), crad pling (Puket, Thailand).

3.432 *Trawls.*—Engulfing bag-like nets which have a non-rigid lower boundary to the mouth.

3.432.1 *Bottom Trawls.*—Trawls which are dragged along the bottom.

3.432.11 *Beam.*—Bottom trawls with a rigid upper boundary to the mouth, e.g., all beam trawls.

3.432.12 *Extended.*—Bottom trawls without a rigid boundary to the mouth, which is kept open by the way in which it is dragged or by otter boards.

3.4321.21 *Pareja.*—Bottom trawls in which the mouth is extended by the use of two vessels, each hauling a warp attached to one extremity of the headline, e.g., pukat gonggong (Malaya), utase and (Japan), junk trawl (Hongkong), etc.

3.432.122 *Otter.*—Bottom trawls in which the mouth is extended by otter boards, thus allowing a non-rigid trawl to be operated by one boat, e.g., all otter & V.D. trawls.

3.432.2 *Floating Trawls.*—Trawls which are dragged through the water but which do not disturb the bottom. These instruments are usually much lighter in construction than bottom trawls and may be dragged near the surface or in mid-water, e.g. :

3.432.21 *Surface*, e.g., nishohiki ukihiki ami (Japan),

3.432.22 *Mid-water/Surface*, e.g., Danish floating trawl.

13

AN ATTEMPT AT CLASSIFICATION OF FISHING METHODS

by

C. J. Bottemanne*

ABSTRACT

A proposal is made for the classification of fishing methods on the basis of a list of four chief activities in fishing and of eight basic forms of gear and fishing devices.

The nature of fishing methods depends on the way certain activities in fishing are combined with the use of certain forms of gear.

There are 4 *chief activities in fishing.*

A. The gear is active and at the same time the centrepoint of fishing, mostly a boat, is active.

B. Only the gear is active.
C. The medium, the water, is active.
D. The fish are active.

The methods under A and B are called active methods, those under C and D are passive fishing methods. This broad distinction was already known before 1938, vide Schna-kenbeck, 1937, but was not further analysed.

There are 5 *basic forms of gear and* 3 *basic kinds of fishing devices* namely :

1. The V-shaped collector.
2. The surrounding wall.
3. The entangling mesh.
4. The hook.
5. Harpoons and missiles.
6. All contacting devices except 4 & 5.
7. Diffusing devices.
8. Deceiving devices.

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These basic forms of gear and devices are used all over the world. Any combination of one or more of these basic forms, with one or more of the basic activities, constitutes a fishing method. The following examples may illustrate this.

1. *The V-shaped collector* falls under A as the ordinary trawl net ; under B as the Danish seine and as the beach-drag net, with the beach as centre-point ; under C as the djermal of Bagan Si Api Api; and under D as f.i. the Japanese muro-ami reef net. In all these cases, there is a strong linear movement, either of the net itself, as under A and B, or of the water as under C, or of the fish, as under D, whatever may be the reason, in the last case, of this movement.

2. *The surrounding wall* will be found as a purse seine under A; as a cast net and as a beach seine under B. Under D many surrounding walls are found, as f.i. bamboo fences, enclosures and barriers, which the fish enter at high tide.

Seines with bags as f.i. the lampara, might sometimes be taken as a combination of 1 and 2 together, under B or A.

3. Gear using the *entangling mesh* will be found under A as a Dutch 2-boat net, towed as a seine. A similar net could be imagined also under B. Under C the different kinds of entangling nets are found everywhere, as the so-called fixed nets. Under D, of course, drift nets belong.

4. *Harpoons* and missiles hardly need further comment.

5. The *hook* will be found under A as trolling apparatus and in the shape of the hook and pole for tuna. These cases are the second example of a more complicated combination, as the active gear is chased by a fully-active fish. Under B the hook will be found in the shape of the active, vertically-hauled, entangling hook. Under C as the passive hook, entangling fish are swept past by the tide, as f.i. in Bagan Si Api Api. D covers the ordinary hand and long line.

6. *The devices mentioned under* 6, such as nooses, and even human hands, also hunting animals, spears, etc., though used extensively, especially in the tropics, are generally found in very small-scale fishing, mostly near or at the shores.

These devices, which may be active spears as well as passive nooses, all contract one or a few fish individually.

7. *Diffusing devices* embrace all those devices by which the fish is poisoned, suffocated, killed or numbed by explosives, or paralysed by electricity. The material or the force are diffused through or with the medium, the water. In the case of electricity, the fishing method may be fully active.

Points 6 & 7 are adopted from T. W. Burdon, (1951).

8. *The deceiving devices* mostly use rooms into which the fish are induced to enter, but which they are not intelligent enough to leave by the existing way out, f.i. weirs, lobster-pots, bubu's, the bamboo fishing stakes of Java, etc.

The classification given above should be supplemented with other distinctions, which may separately differ for every single fishing method. An important point is f.i. whether the fishing method as such has taken into account beforehand the reaction of fish to gear at the moment of catch, or has to cope with this reaction at the last moment. In the first case, the fishing may be called *automatic*, as f.i. in the case of the trawl; in the second, *manipulating* (Bottemanne, 1947), as f.i. in the case of many lampara nets. Important also is the question whether the efficiency of a fishing method is much strengthened by the use of lights, lures, etc. A further description of all the factors will, of course, be necessary to get a complete technical picture of a certain fishery.

It will be clear that, in general, active automatic methods will command the largest amount of cubic feet water per unit of time, and therefore, compared with other methods chiefly catching the same species in the same area, will have the largest catches. Tropical methods, in which passive and manipulating methods prevail, do not as a rule command large amounts of water per unit of time, as compared with methods used in the colder zones. Nevertheless the property of the populations of the fish to be caught and the environment forbid to draw the conclusion, that active automatic methods should be introduced on a large scale in the tropics. Careful preceding investigation is necessary. Still, fishing can be more "activated" in the tropics by the use of powered vessels. It stands however to reason, that under these conditions only the smaller powered vessels will hold commercial possibilities, such as is largely the case in the colder zones as far as methods under C and D are concerned.

SUMMARY

For the classification of fishing methods 2 sets of factors are important, namely the 4 chief activities in fishing and the 8 basic forms of gear and of fishing devices. Both sets of factors are discussed. The nature of the fishing method is determined by the definite combination of one or more of the activities mentioned, with one or more of the basic forms of gear. Examples of the most important

combinations are given. The difference between tropical fishing methods and those of the colder zones is touched.

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SUR LA PISCICULTURE AU CAMBODGE

PAR

M. M. LAFONT ET SAVOEUN

ABSTRACT

An account is given of the principal features of cultural practices employed in Cambodia in relation to the two chief groups, known as white fish and black fish, respectively.

La pêche dans les eaux douces du Cambodge produit déjà une énorme quantité de poissons, bien supérieure à la consommation locale. Malgré cela, en plus de ces ressources naturelles, il existe dans plusieurs régions de petits élevages de poissons choisis parmi les espéces les plus prisées des consommateurs et supportant bien les conditions d'habitat en viviers.

Les espéces les plus couramment rencontrées dans ces élevages sont classées par les Viêtnamiens en 2 catégories :

1°.—Poissons blancs

Pangasius Sutchi Fowler et *Pangasius micronemus* Blkr. (Ca Tra)

Pangasius Larnaudii Bocourt (Ca Vo)

Les trois espéces ci-dessus sont trés souvent élèvées ensemble.

2°.—Poissons noirs.

Clarias batrachus (L.)

Anabas testudineus (Bloch)

Ophicephalus striatus (Bloch)

Ce sont des Viêtnamiens venus de Cochinchine, parfois aussi des Chinois qui pratiquent ordinairement ces élevages. Nous n'avons pas rencontré d'éleveurs cambodgiens.

ELEVAGE des POISSONS BLANCS

(*Pangasius Sutchi* Fowler—*Pangasius micronemus* Blkr.—*Pangasius Larnaudii* Bocourt)

Matériel : Il y a deux modes d'élevage de ces poissons.

(a) en viviers flottants directement immergés dans un cours d'eau. Ces viviers sont construits soit en bambous, soit en bois. Ils ont en géneral les dimensions suivantes :

Longueur : de 7 à 10 métres.

Largeur : de 2,50 ā 4,50 mētres.

Hauteur : de 1,50 à 2 métres.

Un vivier en bambous de 8m de long sur 4,50m de large coûte environ 2.000 piastres et peut servir deux années, à condition de le remettre sérieusement en état au bout de la Iére année. Un vivier en bois vaut prés de 10.000 piastres, car il faut choisir un bois résistant bien dans l'eau. Pour abriter les poissons du soleil, une partie du vivier est couverte soit par des paillotes, soit par des plantes aquatiques, ordinairement des *Eichhornia crassipes* (luc binh). Dans un vivier ayant les dimensions ci-dessus, il est courant de mettre de 7 à 8.000 poissons.

(b) en mare ou étang aménagés de facon â permettre le remplissage pendant la période des hautes eaux, en empechant toutefois par des claies l'entrée des poissons dont certains s'attaqueraient aux jeunes Pangasius. Il faut aussi pouvoir retenir une partie de cette eau au moment de la décrue. La densité des poissons mis en élevage en étang sera plus faible qu'en vivier, l'eau ne se renouvelant pas continuellement. Dans un étang ayant les dimensions suiv-

antes : longueur 130m, largeur 70m, profondeur aux basses eaux 5m, l'exploitant élevait 40.000 Pangasius.

Alevins : En remontant le Mékong, dans la province de Kompong-Cham, en particulier à Péam-Chiléang, on trouve une grande quantité d'alevins de Pangasius que l'on pêche vers les mois de Septembre et Octobre. Quelques pêcheurs sont spécialisés dans cette capture. Ils revendent les alevins de 13 à 20 piastres le mille. Mais bien souvent les éleveurs préfèrent de procurer des jeunes Pangasius pesant dèjà 80 à 150 grammes. Ces jeunes coûtent actuellement de 130 à 180 piastres le mille. On en prend beaucoup au filet pendant les mois de Février, Mars, Avril dans le Tonlé-Sap et les Grands Lacs. Ceux qui viennent de la règion des Lacs sont amenés en jonques-viviers. Ils sont préférés par les éleveurs et coûtent plus cher car, déjà habitués à vivre en viviers, ils résistent mieux. Un éleveur installé sur le Tonlé-Sap-à Phnom-Penh, nous disait avoir eu parfois les 2/3 de morts lorsqu'il achetait des jeunes Pangasius capturés sur place, dans le Tonlé-Sap, par les pêcheurs au filet. Ceci n'entraîne d'ailleurs pour lui aucune perte financière. Les poissons qui meurent sont aussitôt salés et vendus ensuite de 4,50 à 5 piastres le Kilo (ca yêu ôp). Comme il faut de 20 à 30 poissons pour faire un Kilogramme de poisson salé, l'eleveur récupère à peu près son prix d'achat. En général on doit compter au minimum une mortalité d'au moins 15% qui se produit pendant les premiers jours de la mise en viviers. Il faut de 8 à 10 jours pour que le poisson s'habitue à son nouveau genre de vie ; pendant cette période on ne lui donne presque pas à manger. Une fois les poissons habitués, les pertes deviennent trés faibles, sauf accident, pollution de l'eau par jet de mazout des bateaux, quelquefois par maladie.

Nourriture : Les jeunes Pangasius pesant 100 grammes en moyenne au moment de leur mise en vivier atteindront au bout de 8 à 10 mois une taille marchande (de 1 à 1,2kg). Pendant cette période il faudra leur fournir la totalité de leur nourriture ; en effet, les apports de l'eau traversant le vivier sont pratiquement négligeables. Ces poissons élevés en vivier paraissent accepter comme nourriture à peu près tout ce qu'on leur donne. Ce qui guidera le choix de l'èleveur sera uniquement le prix de revient de la ration. Le plus couramment, on les nourrit avec :

(a) des petits poissons " ca linh " (nom collectif pour les espèces suivantes : *Dangila siamensis* Blkr., *Thynnichthys thynnoides* Blkr., *Osteochilus spilopleura* Fowler, *Cirrhinus Jullieni* Sauvage) hachés plus ou moins finement suivant l'âge des Pangasius. Pour les adultes on les coupe en 3 ou 4 morceaux ; pour les très jeunes alevins ils sont transformés en une sorte de pâté que l'on enferme dans une toile fine qui est alors agitée dans l'eau du vivier.

(b) du bananier haché et mélangé avec du son de riz, dans la proportion suivante : 2/3 de bananier et 1/3 de son.

(c) des liserons d'eau (*Ipomoea aquatica*) hachés et autres petites plantes aquatiques.

(d) du mais cuit :

(e) des déchets de haricots soja laissés par la fabrication du *vermicelle* chinois.

De notre enquête auprès de différents éleveurs, il ressort que la base de la nourriture au cours des 8 à 10 mois d'élevage est constituée par du petit poisson. Il est trés difficile d'obtenir des precisions sur la quantité de nourriture donnée chaque jour. Il semble que dans la plupart des cas les poissons en vivier sont insuffisamment nourris, sauf pendant les périodes de passage des bancs de " ca linh ". Un Pangasius adulte pourrait absorber environ 150 grammes de petits poissons hachés par jour.

Maladie : Les Pangasius sont parfois sujets à une maladie (nécrose de la peau) se manifestant par l'apparition de taches blanches qui s'agrandissent de jour en jour. Cette maladie paraît être d'origine parasitaire. Si on n'arrête pas son développement, les poissons meurent dans les huit jours. Le seul remède utilisé par les éleveurs est de la chaux de coquillage mélangée à un peu de terre argileuse ; ils en confectionnent une pâte qui est jetée dans le vivier sous formes de boules. Les *Pangasius larnaudii* (ca vo) grossissent plus vite que les *Pangasius sutchi* (ca tra) mais, par contre, ne dépassent pas 1 kilo à 1,5kg. Les *Pangasius sutchi* élevés 2 et 3 ans en vivier peuvent atteindre 4 et même 5 kilos.

Précautions à prendre pour l' élevage : On peut élever ensemble des *Pangasius larnaudii* et des *Pangasius sutchi* ; mais il faut éviter de mélanger des poissons de tailles différentes. Le vivier doit être placé dans un endroit autant que possible abrité du vent et des remous. La nourriture est distribuée 2 fois par jour, matin et soir. Les Pangasius préfèreraient le poisson légèrement fermenté. Souvent l'eleveur ne distribue les petits " ca linh " que 5 à 6 heures après les avoir pêchés.

Importance et Rendement de ces élevages : Les principaux centres où on pratique ces élevages se trouvent dans la région de Kompong-Cham et Kratié (sur le Mékong à 150 km en amont de Phnom-Penh). Par exemple sur le Prek Chhlong (situé en aval de Kratié) il y avait, l'année derniére, dans un seul village, 70 viviers. L'insécurité qui

règne actuellement dans la région, a provisoirement arrêté cette activité.

A Phnom-Penh même nous avons pu relever 5 élevages. On en trouve aussi couramment dans les provinces de Kompong-Chhnang, Prey-Veng, Kandal. Un éleveur ayant 3 viviers de 9m de long sur 4,50m de large produit chaque année environ 20 tonnes de poissons vendus de 4 à 4,50IC$ le kilo. Pour une recette de 80.000 piastres, ses principaux frais seraient approximativement:

Personnel : 3 coolies à 300$ pendant un an	10.800$
Achat des jeunes *Pangasius* : 30 mille x 150$ 0/00 ..	4.500
Amortissement des viviers : 1.500$x3	4.500
Nourriture (en plus des petits poissons péchés) en moyenne 100$ par jour, pendant 10 mois ..	30.000
Frais de stationnement : 90$ par mois	1.100
	50.900$

Soit au total environ 50.000 piastres, ce qui lui laisserait un bénéfice théorique de 30.000 piastres par an.

ELEVAGE des POISSONS NOIRS

Lélevage des poissons noirs se fait seulement dans des mares naturelles ou creusées artificiellement, jamais en viviers. Ce sont surtout des Vietnamiens qui s'adonnent à cet élevage dans les régions de Kandal, Prey-Veng et Takeo.

Description d'une installation type située à Kompong-Cham : Dimensions de la mare : 50 mètres de long sur 25 mètres de large, profondeur 3 mètres aux hautes eaux, 1,50m en saison sèche. Autour de la mare sont plantés des cerisiers du Japon (*Muntingia calabura*) dont les poissons mangent les fruits. Sur l'eau flottent des *Eichhornia crassipes* dont les racines servent á la fois de nourriture et d'abri pour les poissons.

Récolte des alevins : Les alevins d'*Ophicephalus striatus* Bloch sont capturés pendant les hautes eaux (Juillet) dans les terres inondées à l'aide d'un filet à mailles très fines. Les alevins de *Clarias batrachus* (L.) et *Anabas testudineus* (Bloch) sont capturés uniquement dans les rizières à l'aide de petites nasses finement tressées. En général les éleveurs se procurent les alevins qui leur sont nécessaires en les achetant à des pécheurs spécialisés qui en font le commerce. Leur prix était, en Juillet dernier, de 5 piastres le kilo environ. Les alevins d'Ophicephalus ont de 3 à 5cm de long. Dans certaines régions, on préfère choisir pour l'élevage des jeunes ayant déjà 15cm de long qui sont plus résistants. Les alevins sont triés et on choisit ceux qui sont de taille à peu près équivalente. Dans le bassin ci-dessus, on met environ : 8.000 *Ophiocephalus striatus*, 2.500 *Anabas testudineus*, 1.000 *Clarias batrachus*. Ces trois espèces vivent assez bien ensemble. Toutefois, il se glisse toujours un certain nombre d'alevins d'*Ophicephalus micropeltes* C.V., trés voraces qui ont échappé au triage. Ils vont détruire une partie des alevins d'*Ophicephalu striatus*.

Nourriture : Pendant la première année on leur distribue comme nourriture environ 100 kgs de mais par semaine. Ce mais est bouilli préalablement de facon à obtenir un gonflement et un ramollissement des grains. A la fin de cette première année d'élevage, ces différentes espèces atteignent les poids suivants :

Ophicephalus striatus	0,800kg
Clarias batrachus	0,200kg
Anabas testudineus	0,080kg

Ces poissons ne sont vendus qu'après une deuxième année d'élevage ; ils atteindront alors respectivement les poids de : 1,300 kg, 0,350 kg, et 0,120 kg.

Le rendement total en poisson de cet élevage serait d'environ 10 tonnes au bout de deux ans. Le prix de vente moyen de ces poissons a été cette année de 4,50IC$ le kilo, soit une recette totale d'environ 45.000 pias tres (pour 2 ans). Le propriétaire (pour qui l'élevage ne constitue qu'une recette accessoire) nous a indiqué approximativement le montant de ses frais (pour les deux années) :

Achat des alevins	400$
Matériel, Entretien des digues etc.	5.000
Personnel	6.800
Nourriture	14.000
	26.200$

Soit un bénefice d'environ 19.000 piastres pour deux ans.

CONCLUSION

L'extension des élevages de poissons par les méthodes en usage au Cambodge nous paraît possible étant données les conditions très favorables qui s'y trouvent réunies :

1°.—Il existe déjà dans les eaux douces du Cambodge au moins 6 ou 7 éspèces de poissons supportant bien les conditions de vie en viviers, ayant une chair très prisée des consommateurs Indochinois,

ce qui permet d'en réaliser la vente à un prix rémunérateur.

2°.—Les alevins ou même mieux les jeunes poissons de ces espèces se trouvent facilement et en grand nombre.

3°.—La méthode d'élevage en vivier est susceptible d'un très grand développement, les endroits propices ne manquent pas, le prix des viviers en bambous est relativement faible compte tenu des tonnages de poissons pouvant y être obtenus (5 à 7 tonnes de poissons pour un amortissement de 1.500 piastres).

4°.—La base de la nourriture des Pangasius est constituée par les " ca linh " (nom collectif pour les espèces suivantes : *Dangila siamensis* Blkr., *Thynnichthys thynnoides* Blkr., *Osteochilus spilopleura* Fowler, *Cirrhinus Jullieni* Sauvage) et autres petits poissons pêchés en grande quantité au Cambodge. Le seul inconvénient réside dans le fait qu'il est impossible de se procurer régulièrement et pendant toute l'année ces petits poissons. A certaines epoques, il y en a des bancs énormes, mais pendant la saison de remontée des eaux, il y en a trés peu. Les éleveurs doivent alors acheter : soit du maïs, soit du son, soit des déchets de soja, et, par mesure d'économie, ils ne donnent à manger à leurs poissons que le minimum pendant toute cette période, ceux-ci maigrissent, deviennent moins résistants aux maladies, ce qui entraîne toujours des pertes. Il y aurait un moyen de remédier á cet inconvénient : les " ca linh " se pêchent en abondance de décembre à mars dans les fleuves et un peu plus tard sur les lacs. Ces poissons très gras sont surtout utilisés actuellement pour la fabrication de l'huile, et la totalité des déchets restant après cuisson des corps, sont rejetés. C'est là une perte considérable de matière azotée qu'il serait intéressant de récuperer. Nous avons déjà utilisé, dans de précédents essais, ces déchets pour la fabrication de farine de poisson ; mais cette farine contenant encore une forte proportion de matière grasse, 17 á 22%, n'a pas trouvé d'acheteurs, car elle est trop grasse pour l'alimentation du bétail. Nous pensons que cette farine pourrait être utilisée dans l'élevage des Pangasius. La transformation des déchets de " ca linh " en farine est assez simple à condition d'utiliser une presse pour éliminer la plus grande partie de l'eau qu'ils contiennent et permettre le séchage au soleil. Nous avons l'intention cette année de tenter une expérience d'è levage de Pangasius dans un vivier que nous venons d'installer dans le Tonlé-Sap devant notre station expérimentale. Ce vivier pourra recevoir 3 à 4.000 jeunes ayant 10 à 15 cm qu'il est facile de se procurer auprès des pêcheurs voisins. Nous pensons étudier le rendement économique de l'élevage des Pangasius, essayer différentes rations et en particulier la farine de poisson.

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FISH CULTURE IN PAKISTAN

by

Nazir Ahmad*

ABSTRACT

A brief account is given of the fish cultural practices employed in fresh and brackish waters in Pakistan.

Taken as a whole, the present fish-production in Pakistan is not quite sufficient to meet the demand of 80 million people. The sea, *khals* (Channels), rivers, *bheels*, tanks, etc., are exploited to smaller or greater extent by old methods entailing labour and expense, but the output per man-effort is not a fraction of what is obtained in advanced countries. With the backwardness, illiteracy and poverty, it is not possible for Pakistani fishermen to make rapid advances and it is believed that the remedy lies in steady and slow progress.

The writer attaches the greatest importance to tank culture for ameliorating the economic condition of fish culturists and for supplying quality fishes at cheap rates especially at places far away from rail and motor roads. It is especially so in the province of East Bengal where the communication is difficult, preservation facilities are almost non-existent, the tanks are innumerable and ideal conditions exist for the growth of fish. In the Punjab the communication is good, but the rivers are few and are in short supply during winter months and thus tank

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culture can play an important rôle in stepping up the much wanted fish-production. In Sind there are extensive impoundments, but no serious efforts have been made so far to utilise them. The other provinces and states in Pakistan are not very important from the point of view of tank fisheries and are not discussed in this short note.

TANKS AND CARP CULTURE

In East Bengal 1,70,539 tanks have already been surveyed. Most of these tanks were perhaps never meant for pisciculture and so do not conform to any approved standard. These include shallow and deep tanks, small and big tanks, and tanks circular, rectangular and irregular in outline. But whatever their shape and depth, they can be fruitfully utilised for producing the protective protein food. Out of the tanks surveyed, 40% are lying derelict and are mostly covered with water-hyacinth and other aquatic vegetation and have turned into hotbeds of malaria, or are full of bottom silt and predaceous animals. Most of the remaining tanks are being utilised for raising fish and this is done by simply introducing fry of mixed species of fish into tanks of all dimensions. No attempt is made to stock the tanks according to the availability of food at different strata of water and once fry are introduced these are left there for growth till required for consumption. The Directorate of Fisheries, East Bengal, since the partition of Bengal, has been popularising scientific fish culture by various methods. Departmental fish-seed supply centres have been established in the district and subdivisional towns for supplying quality seeds of the right type for stocking tanks of different depths and areas. The Fishery Officers inspect private tanks and advise the owners of such tanks on the number and species of fish to be introduced in a particular tank. Instructions are also given on manuring of ponds and general management. Demonstration Centres have also been set up where one can learn the technique of pisciculture. Out of the Government nurseries 9,13,018 young fish were distributed to tank culturists during this year.

Just before the partition of Bengal there were only two small Government Demonstration Fish Farms (each including only one tank) in the districts included in the present East Bengal, but now there are as many as thirty extensive farms comprising 138 tanks, one *bheel*, 3 *channels* and a portion of a river, 3 miles in length. All these farms are running as economic units. Every year more farms are being opened. Private parties are not lagging behind and are reclaiming the neglected water areas and are helping to " Grow More Food '.

Due to " *Permanent Settlement* " in East Bengal, it is difficult to make rapid progress in fish culture. Under executive order, however, the tanks can be acquired for leasing to interested parties, but that is a cumbersome process. If some law could be passed under which it might be punishable to keep the tanks unused, I think much headway could be made and the tanks could be turned into fruitful sources of fish supply. The derelict tanks require lot of money for improvement and this difficulty can be overcome either by advancing loan to deserving parties or by organising fish-cultural societies to take up the work. Some progress has been made in this direction but much remains to be done.

In the Punjab impoundments are not very many and some dry up during the winter season. These include village ponds, ornamental ponds, *dhands*, lakes, etc. The Fish Section of the Agriculture Department, Punjab is trying its best to utilise these tanks for fish production. As compared with 20 before partition, there are now as many as 750 departmental rearing tanks in the province. The number of stocking tanks has similarly risen from 18 to 70. It is also being planned to raise fish in highly saline water-logged areas of the province and for this purpose 500 fish, *Tilapia mossambica* (Peters), have recently been imported from Singapore.

SALTWATER FISH CULTURE

The saltwater *bheries* (akin to Mulletries) are important in the district of Khulna of East Bengal. These are prepared by putting up strong embankments on the banks of the tidal rivers enclosing areas to be reclaimed. For the preparation of the embankments, earth is scooped out resulting in the formation of canals. In the *bheries* saltwater fishes like, *Lates calcarifer* (Bloch), *Mugil tade* Forsk, *Mugil parsia* Hamilton and some species of prawns are grown. During the breeding season of the estuarine fishes, the sluices are opened to allow water and eggs and fry of fish and young prawns to enter. As a result of this the enclosed soil becomes impregnated with salt, but monsoon rains wash it off and the soil becomes fit for paddy culture. Thus fish and paddy are grown simultaneously. The paddy fields serve as grazing grounds and canals as the stocking or fattening tanks for the fish. In the district of Chittagong certain salt-water *khals* (channels) are being cultured advantageously and are giving encouraging results. The *khal* culture is also now becoming popular and has a great scope of extension.

FISH SEED

Since our major carps, viz., *Catla catla* (Hamilton), *Labeo rohita* (Hamilton), *Cirrhina mrigala* (Hamilton), *Labeo calbasu* (Hamilton), etc., do not breed

in confined waters, the question of their seed supply for cultivation is a vital one. Fortunately in East Bengal we have a number of rivers where collection of eggs, larvae and fry of these species is made every year during the breeding season of the fish. The collection is usually a mixture of eggs and young ones of a number of fishes, both predaceous and non-predaceous. From one of the rivers, viz., the Halda, only eggs are collected, and hatched by indigenous methods and transported in earthenware (*handies*) to places where required, by boats, launches, carts, buses and trains. In the year 1949, as many as 6,183 *handies* (each containing from 25,000 to 50,000 young ones) were moved within and outside the district of Chittagong for cultural purposes.

From the river Padma and others only larvae and fry are gathered. These are then passed through suitable sieves with the result that big fry, which mostly belong to undesirable species of fish, are separated from the carp fry. The Padma and other rivers supplied 15,812 *handies* of young ones in the year 1949, including, 9,466 to India.

In the Punjab, mostly fry and fingerlings are collected, but sometimes eggs are also gathered from the rivers. The method of transport here is slightly different. Fry and young fish are carried from one place to another by oxygen carriers. This method has been proved to be quite satisfactory for conditions obtaining in that province.

The pisciculturists introduce the fry into shallow nurseries in order to provide them with suitable environmental conditions. After they grow to a size of an inch or so, these are caught and sorted out. The major carp fingerlings are then introduced into bigger and deeper rearing ponds for a couple of months. The young fish obtained as the result of rearing are finally liberated, according to the feeding capacity of the water, into fattening or stocking ponds for further growth. The "crop" in these ponds is available throughout the year and can be reaped whenever desired.

CULTURE OF PREDACEOUS FISHES

In East Bengal in tanks which are full of vegetation or contain predaceous animals, carps are not introduced but suitable predatory fishes are grown. This practice is, however, not very common and popular. The fishes included in this category are *Wallago attu* (Bl. & Schn.), *Ophicephalus punctatus* Bloch, *Ophicephalus marulius* Hamilton, *Ophicephalus gachua* Hamilton, *Clarias batrachus* (Linn.), *Heteropneustes fossilis* (Bloch). Most of these fish possess accessory respiratory organs which sustain them outside water, and the fish can thus leave their abode and move about from one pond to another. The culture of these fish is, therefore, not advisable near the carp ponds.

FUTURE POSSIBILITIES

There is a very great possibility of extension of tank fisheries in East Bengal, Punjab and Sind and to a certain extent in other provinces and states included in Pakistan. Certain districts of East Bengal further offer opportunities of stepping up salt-water fish-production in *khals* and *bheries*.

Future development of tank fisheries will depend upon the successful solution of the problems like the weed control, eradication of predaceous animals from fishery ponds, artificial feeding of fishes, etc. These improvements are now effected by repeated netting, dewatering the tanks, drying and ploughing the bottom, mixing lime with the bottom-soil and manuring it with organic manures, etc. These methods are costly and in some cases impracticable. The chemicals used for combating the weeds and eradicating the predaceous animals are costly and are also not very effective. The weeds appear again after they are killed by chemicals, and fish with accessory respiratory organs do not easily die, and some migrate from other tanks as soon as the conditions for such migration are favourable.

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INVESTIGATION OF SEA-WEED PRODUCTS IN INDIA WITH A NOTE ON SOME PROPERTIES OF VARIOUS INDIAN AGARS*

by

Francesca Thivy**

ABSTRACT

Research in India on the manufacture of sea-weed products concerns agar, algin, fertilizers, and Iodine. Production on a commercial scale is likely to commence, in the near future, in the case of agar. The yields from various Indian agarophytes as well as the gelation temperatures and gel-strengths of their agars are reported.

The agar shortage experienced by the United Nations during the Second World War engendered investigation of sea-weeds which has resulted in information presented in numerous scientific publications (*vide* Chapman, 1950) and also treated in popular accounts by Newton (1947, 1949), Tseng (1947), Kalmer (1948), and Brook (1949). This paper considers the extent to which the research carried out on the products from Indian sea-weeds and the information available on resources provide grounds for the establishment of industries.

SEA-WEED PRODUCTS OF INDIA

Investigation of Indian sea-weed products concerns agar, algin, fertilizer, and Iodine.

Agar

Agar manufacture was initiated in 1940. The refined product was first processed at the Laboratories of the Council of Scientific and Industrial Research, New Delhi, from a *Gracilaria* from Travancore, by Bose, Karimullah, and Siddique (1943). The product which showed 5.2% ash, by weight, conformed rather closely to the B. P. and U. S. P. specifications.

From *Gracilaria confervoides* of Chilka Lake Chakraborty (1945) prepared agar on the lines of the freezing and thawing method used in Japan (*vide* Adams, 1947). The yield was 25% – 30% of the weight of the sun-dried seaweed; the ash content was 2.5% which compares well with the B. P. criterion of "not more than 5%" and the "Difco" agar analysis showing 3.0%. Mitra (1946) reported that agar was extracted from two species of *Gracilaria* from Chilka Lake and stated that 4 to 5 tons of bleached raw-material were available from the lake annually.

Using *G. lichenoides*, a method of agar refinement not dependent on freezing was introduced by Karunakar, Raju, and Varadarajan (1948) of the Department of Agriculture, Madras. Removal of impurities from the crude gel takes place by leaching which is increased by the presence of bacteria in the water. The product stood the bactro-agar tests; ash was 3.0% by weight and Nitrogen, 0.17% (against 0.22% Nitrogen of "Difco" agar).

Agar was produced in the Department of Research of the Travancore University from 1942 to 1946 by Joseph and Mahadevan (1948). About 4.5 tons of fresh *Gracilaria* belonging to four species, were processed together. Nearly 400 lbs of refined agar were made which met local demands during the war for the preparation of vaccines.

Algin, Seaweed fertilizer, and Iodine

Algin extraction is being investigated by the Madras Govt. Fisheries Department at Krusadai Is., and concerns the Fucales, for the Laminariales, which are the usual source, occur only in the colder waters. Experiments on the value of sea-weeds as fertilizer conducted and reported by Chidambaram and Unny (1947) show that *Sargassum* and *Turbinaria* have high potash- and fair Nitrogen-content and *Gracilaria*, fair Nitrogen- and low potash-content. Composting the two former genera with fish-offal and shark-liver oil sediments, in the ratio of 15 : 3 : 4 by weight for three months, gave an above-average fertilizer having by weight 2.4% Nitrogen, 3.5% potash, and 0.7% phosphates.

Iodine was obtained from *Sargassum* by Joseph, Ganapati, and Ramamurthi (1948). Ratnagiri specimens gave better results than those from Cape Comorin, Tuticorin, and Rameswaram. The maximum yield was 0.203% of the dry weight as against 0.477% for *Laminaria*. There is a seasonal variation in Iodine content in Indian *Sargassum* as with *Laminaria*. Hornell (1918) stated that fresh *Sar-*

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gassum washed ashore on the Kathiawar Coast was roughly estimated at 100 tons per annum.

AGAROPHYTES AND SEA-GRASSES OF THE PAMBAN AREA

Agarophytes

An investigation of the agarophytes of the Pamban area, the stretch of coast about 25 miles long from Mandapam to Kilakarai, and the adjoining islands, was started at the Central Marine Fisheries Research Station, Mandapam Camp, in September 1949, by the present writer. The common agarophytes of the area comprise : *Gelidium micropterum* Kütz., *Hypnea musciformis* (Wulf.) Lamx., *Sarconema filiforme* (Sond.) Kylin, *Gracilaria confervoides* (L.) Grev., *G. compressa* (Ag.) J. Ag., *G. lichenoides* (L.) Harv., *G. crassa* (Harv.) Ag., *G. disticha* J. Ag., *G. debilis* (Forssk.) Boergs., *G.* sp. (1), *G.* sp. (2), *G. foliifera* (Forssk.) Boergs., *G. corticata* J. Ag., *Centroeras clavulatum* (Ag.) Schmitz and *Spyridia filamentosa* (Wulf.) Harv.

Some properties of various Agars

The yields obtainable from ten species of the Pamban area have been found out, as well as the gelation temperature and gel-strength of the refined agar from each of them (*vide* Table I.) The process of preparation was the Japanese method (acidification, sedimentation, freezing and thawing) but with centrifugation. These species range in yield from 12% to 43% of the weight of the washed, sun-dried sea-weed ; their agars vary in gelation temperatures from 26° C. to 46° C. The gel-strength of 1.5% solution of *Gracilaria lichenoides*-agar being taken as the standard and those of the others, in the same concentration, being compared with it, they are found to be roughly one-twenty-fifth to twice that of the first. The commercial value of agars is to a great extent dependent on these criteria.

Gelidium micropterum, an agarophyte not used before, has been found to yield agar of unusual gel-strength. Refined *Gelidium micropterum*-agar fulfils bactro-agar requirements except that of gelation temperature which is in this case 38° C. (for 1% solution) ; whereas it should be 35° C. (for use in poured plates), but the latter temperature can be obtained by mixing with this agar one with a lower gelation temperature.

Abundance of *Gelidium micropterum*

The plant is tough and grows at depths of 1 to 5 ft. (at low tide), attached to coral rocks. It attains a height of 10 cm and branches from the base, the branches bending downwards, dividing several times, and finally bearing stiff, feather-like segments. Its abundance in the Pamban area is being investigated and information on the annual harvestable quantity will be available, it is hoped, in a year from now. On the average 3 lbs of the fresh plant can be cut from a square metre of the reefs, the basal region of the plant being on purpose left behind. A rough estimate for this area of the annual quantity of fresh material of this species available is 10 tons or a tenth, probably, of that of all the agarophytes.

Resources in Agarophytes and Sea-grasses

India imported from Japan during the four years 1934 to 1937 on the average 29 tons of agar which represents about 3,000 tons of fresh agarophytes ; and the resources of fresh agarophytes per annum for the whole of India are roughly estimated to equal the last figure, the possible resources of the Laccadive Is. and the Andaman Is. not being considered. By comparison the tonnage of fresh agarophyte used in the Republic of Korea in 1948 was 1,103, that of fresh *Gracilaria* known at present to be available in Australia is about 62,500 (computed from Wood, 1946), and that of fresh agarophytes processed in Japan in the year 1946-'47 was 700,000.

Common sea-grasses of the Pamban area, especially *Cymodocea ciliata*, *C. serrulata*, and *C. australis*, drift in the currents and are deposited in banks, at low tide, in many small coves of the Gulf of Manaar and its islands. A bank, 200 yards long, composed of dead leaves, twice daily formed, and twice daily washed away to a greater or less extent, was found to weigh on the average 27 tons from weekly estimation during the month of June, 1950. The figure gives an idea of the great amounts of sea-grasses cast up and remaining unutilized. Whereas algae are used in many countries as manure, sea-grasses also serve this end in the Republic of Korea where the annual tonnage during recent years was from 7,000 to 23,000. Marine plants have powers of extracting the scarcer elements from the sea and can restore them to the land ; sea-weed and sea-grass fertilizers gain in usefulness when considered as sources of trace elements.

CONCLUSIONS

Work on certain Indian sea-weeds indicates that other sea-weeds and the sea-grasses could also be useful as fertilizer. The success achieved in extracting Iodine from Indian *Sargassum* will have practical value were it to be a by-product of algin manufacture, for the large resources in sea-weed required for an Iodine industry cannot be expected

from Indian waters. Investigation of agar manufacture has advanced sufficiently as to be able to provide information on raw-materials and the adaptation of the freezing method to Indian agarophytes.

The Indian seaweed industry being in the pioneering stage implies the need for investigation of the biology, resources, and nutritional values regarding useful sea-weeds and of the technological and chemical problems regarding the products yielded by them.

SUMMARY

Research accomplished on Indian agarophytes shows they afford favourable yields of refined agar. A large number of agarophytes are known in Indian waters, *Gelidium micropterum* being the most important both for yield and quality. The agar yield of ten species of the Pamban area and the gelation temperatures and gel-strengths of their agars have been found out. Quantitative work on agarophytic resources has been started.

Algin manufacture is in its early phase in India. Reference is made to the favourable results which were obtained from composting certain seaweeds with fish wastes and to the maximum yield of Iodine which was found in Indian *Sargassum*.

The writer wishes to express her indebtedness to Drs. H. Srinivasa Rao and N. Kesava Panikkar for guidance received during the investigation.

TABLE I

SOME PROPERTIES OF VARIOUS INDIAN AGARS

Ser. No.	Species	Percentage yield from washed, sun-dried seaweed	Gelation Temp. of 1.5% solution °C.	Gel-strength of 100 c.c. of 1.5 % solution kept in a standard 250 c.c. beaker at room temp. for 24 hours. Gms per sq. cm
1.	*Gelidium micropterum* Kütz. ..	43	40	250
2.	*Gracilaria crassa* (Harv.) J. Ag. ..	30	46	140
3.	*Gracilaria* sp. (1) ..	26	34	80
4.	*Gracilaria* sp. (2) ..	24	39	70
5.	*G. lichenoides* (L.) Harv. ..	19	43	130
6.	*G. compressa* (Ag.) J. Ag. ..	17	40	60
7.	*G. corticata* J. Ag. ..	17	40	10
8.	*G. foliifera* (Forssk.) Boergs. ..	12	40	15
9.	*Hypnea musciformi* (Wulf.) J. Ag. ..	24	26	65
10.	*Sarconema filiforme* (Sond.) Kylin ..	19	38	5

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17

A SURVEY OF THE SEA FISHERIES OF INDIA*

by

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ABSTRACT

A preliminary account is given of the design and technique of the sampling method employed for estimating the landings of sea fish at some selected centres along the East and West coasts of India. Statistics of marine fishing villages, fishing populations, boats and nets are presented along with approximate percentages of the occurrence of important fishes and also the estimated monthly landings of fish during 1949 at some representative places.

India, with a long coast line of about 2,900 miles, has a vast fishable area but only a narrow stretch of water 5-7 miles from the shore is exploited. The degree of exploitation of the inshore waters has not been fully assessed. The fishing industry is diffuse and is in the hands of fishermen without education ; besides, neither the implements of fishing nor the fishermen are licensed or registered. As a result, the industry, in spite of rich potential resources, is in the stage of a cottage industry. A detailed survey of the existing resources is an essential and urgent necessity for any scientific and administrative programme of development and exploitation of the industry. But in view of the peculiar circumstances prevailing in India, a complete or total enumeration of the data on all the aspects of the fisheries is not possible at present. Hence recourse has to be made to the sampling method, particularly with reference to the problem of estimation of landings. The present paper deals with the design and technique of the sampling method adopted in the pilot survey carried out by the Central Marine Fisheries Research Station, Mandapam. Though the programme is still in the early stage, it is presented here in view of the interest it may have to countries where fisheries are underdeveloped and complete enumeration for estimating production is not practicable.

RECRUITMENT AND TRAINING OF PERSONNEL

The first step in this work was obviously the training of a batch of suitable persons who could carry out this survey. The persons carrying out the survey must possess not only adequate knowledge of fishery science but should also know the language of the area in which they are to work, since they have to deal with illiterate fishermen. And in a multilingual country such as India, this places a special burden. Twelve graduates representing the various languages in the different zones where they have ultimately to work were recruited, and it was subsequently thought that it would be better for them to undergo a course of six months' intensive training in fisheries. This was necessary because not all the persons chosen were graduates in Zoology, although the majority were persons who had completed a course of training under the all-India Fisheries training scheme. The training subsequently given at the Bombay Sub-station mainly consisted of—

(1) *On the biological side*—Identification of fish, dissection of fish for study of stomach contents, conditions of gonads and parasites; study of plankton along with determination of salinity and specific gravity of sea water, and

(2) *On the Survey side*—the study of different kinds of craft and tackle existing in India, their advantages and drawbacks, the economic status of the fishing populations in relation to existing fishery conditions, necessity of survey, how statistical surveys can be carried out, importance of the preliminary field data and how to present them for detailed analysis.

PRELIMINARY SURVEY

The entire coast-line of India was divided into 12 somewhat unequal zones after taking into consideration the geographical conditions and the regional language. In each zone, approximately 250 miles long, one survey assistant conversant with the local language, was posted with instructions to conduct a preliminary rapid survey of the fishery conditions in the respective zone. In this survey, the assistants acquainted themselves with all the marine fishing villages in their respective zones and collected, village by village as far as possible, the complete statistics of fishing population, boats and nets, with some information on the socio-economic condition of fishermen. They also gathered information regarding

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the availability of different species of fish and the seasons of their occurrence. These data were subsequently checked and confirmed by a survey during the off-season in the following year and are tabulated in appendix I.

INTENSIVE STUDY

More intensive survey of fisheries with the ultimate object of assessing the resources of sea-fisheries of India was next taken up. The resources available at the disposal of the Central Marine Fisheries Research Station did not permit either total enumeration or even a full-scale random sample survey for the entire coast-line of India. The survey for estimating the total landings is therefore confined initially to a few important centres on both coasts of India but in course of time it should be possible to extend the present machinery to cover the entire coast-line of India.

Five standard forms for collection of information on inventory and production were prepared and given to the survey assistants for recording detailed information. On the inventory side, statistics were collected on a complete enumeration basis. The forms III, IV and V are designed to collect complete statistics on boats, nets and marine fishing villages. The collection of production statistics is based on the sampling method for which forms I and IV are prescribed. Form I is meant for examination of sample boat-net combinations with reference to the following items : the type of boat-net combination, the number of crew, the distance from the shore where fishing took place, the total weight of the fish landed and the separate weight for different species of important fishes. Form VI shows the number of working boat-net combinations of different types at each place of observation. It also shows the number of days when there was no fishing during the month.

Each survey assistant was asked to visit all the centres in his zone twice a month, once in each fortnight, the duration of stay at a centre each time depending on the total number of centres selected in the zone. In the case of a three-centre zone, the duration of stay at each centre was four to five days in a fortnight and thus data for eight to ten days was collected during the whole month. Based on the data of these days, a monthly estimate of landings was made for each place.

After preliminary trials, the unit of sampling was chosen to be a boat-net combination. Thus a catamaran with hooks and lines and a catamaran with gill net are considered to be two different types of sampling units. It may be noted here that the quantity and quality of catch depend not on the boat but mainly on the type of the net used. Hence the selection of a boat as sampling unit is not quite satisfactory, when various types of tackle are operated simultaneously in one place.

On every day of visit to a fishing village, the survey assistant is to determine at once from local enquiry, the approximate number of different boat-net combinations that have gone out fishing. Subsequently he also checks this number and records the exact number in form VI. From this the sample size for each boat-net combination for the day is determined in accordance with the proportion of all boats (10%) to be examined. As the boats are not numbered, the randomness of the sample is assured by choosing every tenth boat that returns from fishing.

METHOD OF ESTIMATE

In broad out-line the method of estimation is based on the situation for a three-centre zone where observations have been made for about 8-10 days at each centre in a month. These observations are sorted out according to the different boat-net combinations used and the average catch in respect of each boat-net combination used is worked out. From form VI, the number of different boat-net combinations working at the place for those 8-10 days is obtained, from which is calculated the average number of different boat-net combinations working at a place per day. These figures, when multiplied by the corresponding average figures of landings from different boat-net combinations, give the daily estimated landings by each of the different combinations in use at the place and when added together give the estimate of daily landings. This, multiplied by the number of total fishing days in a month gives the total monthly landings.

From preliminary analysis it is found that the percentage error of the estimated landings at different places does not exceed ten per cent. Besides, for each boat-net combination, the weight of different species of fish are tabulated separately for all these samples for the 8-10 days under observation and the percentage of each to the total weight of all fish obtained is calculated. This gives an indication of the degree of availability of different species of fish in a month and, on this basis, approximate percentages of important fish have been given zone by zone in Appendix II.

ESTIMATED FISH LANDINGS

Appendix III shows the estimated monthly landings of fish in tons at some representative places

along both coasts of India during 1949. As the work was begun in January, 1949, systematic statistics could not be collected at some places in the first month or two.

It will be seen that there is much variation in these figures from month to month and the period of good fishing at some places does not synchronise with such periods at other places. The main reasons for these variations appear to be the south-west and north-east monsoons and the appearance and disappearance of large groups of shoaling fishes.

DIFFICULTIES IN COURSE OF SURVEY

The main difficulties encountered in the course of the work may now be examined.

(1) *Lack of co-operation from the fishermen*—The fishermen have such deep-rooted prejudices and superstition that the survey assistants in the beginning faced a considerable reluctance to give correct information. By moving among them constantly and by explaining to them the motives of the survey, the assistants have won their confidence to some extent. Even now they have to face intense opposition in some places. This attitude of the fishermen arises from their fear that their century-old right to exploit the sea may be curbed by the imposition of taxes and that the survey assistants are secretly assessing their capacities for paying such a tax.

(2) *Transport difficulties*—In many zones, the fishing villages have very inadequate means of communication. The assistant may have to wade through mud, sand and paddy fields to reach a fishing village. At the village, they may have neither shelter nor food. They may therefore have to carry provisions with them over long distances. These physical hardships combined with local opposition in certain cases are a serious strain on the survey assistants who must work single handed.

(3) *Financial difficulties*—For any planned method of collecting statistics even by the sampling technique, many people are required, and this requires a substantial allotment of funds. It is necessary that the cost of collection of statistics should be met by the fishing industry but the men engaged in fishing are entirely against the idea. Only twelve survey assistants were recruited to collect the statistics, each having for observation a coast-line of about 250 miles, on an average. Collection of statistics is therefore confined to two or three fishing centres in each zone for the present. It is obvious that this is not an ideal arrangement.

(4) *Leave etc.*—Since only one survey assistant is available to collect data within each zone, and since there are no spare hands to replace them, gaps and discontinuity in the routine collection of data are bound to occur when for reasons of health or otherwise the assistant is forced to be away from duty. Attempts are now being made to avoid such discontinuities in the data by sparing the services of other workers at the respective centres in places where establishments of the Central Marine Fisheries Research Station exist. A further extension along the same lines will be the help of State fishery organizations in making the data relating to the different zones complete.

SUMMARY

As a first step in collecting comprehensive statistics of the Indian fishing industry a preliminary survey has been made along the entire coast-line of India, carried out for a period of about six months, and collecting information about fishing population, boats, nets etc. on total enumeration basis.

Based on these data a sampling technique was evolved to estimate the total production of marine fisheries. The design of sampling is a multi-stage one, with a few centres selected from each zone in the first stage and a certain percentage of the boat-net combinations from these centres being aken in the ultimate stage.

The method of estimation is briefly described and a statement of estimated monthly landings of fish at important centres along both coasts of India during 1949 is given, supplemented by computed figures of landings for the whole of India. In addition, approximate percentages of some important fishes, zone by zone, are also furnished. The difficulties met with during the course of this investigation are briefly discussed.

ACKNOWLEDGMENT

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APPENDIX I

Showing the statistics of marine fishing villages, fishing population, boats, nets and computed landings of fish

Zones	Number of fishing villages	Total fisher-men popu-lation	Types of boats			Types of nets					Computed landings of fish in tons in 1949
			Catamarans	Boats	Canoes	Shore seines or in-shore drag nets	Fixed or stationary nets	Bag nets or boat seines	Drift and gill nets	Other miscel-laneous types	
1. West Bengal and Orissa	127	33,640	2,391	792	..	1,257	3,092	4,079	4,341	2,224	18,842
2. Andhra coast (from south of Gopalpur to north of Vishakapatnam) ..	139	83,404	9,034	850	..	887	..	4,617	20,763	..	54,273
3. Andhra coast (from Vishakapatnam to Masulipatnam)	145	28,885	5,995	5,442	..	560	13,530	3,027	11,635	1,036	24,429
4. Andhra coast (south of Masulipatnam to north of Pulicat lake) ..	108	8,870	2,578	474	..	217	..	1,452	2,697	..	1,308
5. Coromandel coast (Pulicat lake to Cuddalore)	123	51,329	7,874	543	336	535	..	4,700	473	..	12,685
6. Coromandel coast (south of Cuddalore to Devipattanam)	55	9,138	2,086	353	..	..	833	927	5,029	650	11,850
7. Palk Bay and Gulf of Mannar (south of Devipattanam to North of Cape Comorin)	55	35,268	1,502	482	228	1,282	..	853	10,283	..	2,600
8. Travancore, Cochin and South Malabar (Cape Comorin to Ponnani. R.) ..	45	1,59,248	982	..	13,387	..	..	12,948	5,712	3,094	48,659
9. Malabar and South Kanara (north of Ponnani. R. to Mangalore) ..	108	85,115	..	36	6,468	7	..	6,205	3,875	5,063	85,512
10. Kanara, Karwar and Konkan coast (north of Mangalore to south of Ratnagiri) ..	145	85,057	..	2,670	4,349	2,119	11,109	763	41,840	13,628	72,840
11. Bombay and Gujarat (Ratnagiri to Broach)	183	1,61,945	..	3,949	562	..	..	33,315	75,501	35,768	48,447
12. Kathiawar coast (north of Broach) ..	..	..	..	..	..	..	..	..	..	..	..
Total ..	1,231	7,41,899	32,442	15,571	25,330	6,864	28,564	72,886	1,82,169	61,463	3,81,442

APPENDIX II

Showing the occurrence and distribution of important fish with their percentage, zone by zone

Zones	Important fish with approximate percentage
1. West Bengal and Orissa.	Sardines 40% and Anchovy 30%.
2. Andhra coast (from south of Gopalpur to north of Vishakapatnam)	Sardines 25%, Whi e baits 20% and Ribbon-fish 20%.
3. Andhra coast (from Vishakapatnam to Masulipatnam)	Anchovy 30%, White baits 25%, Ribbon-fish 10%, Pellona 10% and Sharks 5%.
4. Andhra coast (south of Masulipatnam to north of Pulicat lake)	No important fisheries.
5. Coromandel coast (Pulicat lake to Cuddalore)	Anchovy 25%, Ribbon-fish 20%, Silver bellies 10%, Big-jawed Jumper 5% and Flying-fish 5%.
6. Coromandel coast (south of Cuddalore to Devipattanam)	Rays 15%, Jew-fish 10%, Cat-fish 10%, Flying-fish 5% and Ribbon-fish 5%.
7. Palk Bay and Gulf of Mannar (south of Devipattanam to North of Cape Comorin)	Perches 50% and Sardines 20%.
8. Travancore, Cochin and South Malabar (Cape Comorin to Ponnani. R.) ..	Sardines 25%, Mackerel 15%, White baits 15%, Big-jawed Jumper 12%, Tunnies 10%, Silver bellies 7% and Prawns 5%.
9. Malabar and South Kanara (north of Ponnani. R. to Mangalore)	Mackerel 20%, Sardines 20%, Prawns 20%, Sharks 15% and Soles 7%.
10. Kanara, Karwar and Konkan coast (north of Mangalore to South of Ratnagiri)	Mackerels 45% and Sardines 15%.
11. Bombay and Gujarat (Ratnagiri to Broach)	Prawns 20%, Bombay-duck 20%, Ribbon-fish 15%, Indian Cod (*Bregmaceros macclellandi*) 10%, Jew-fish 5% and Indian Salmon 5%.

APPENDIX III

Estimated monthly landings of fish in British tons (2,240 lbs) at some representative places during 1949

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
East-Coast—												
1. Puri	—	114.3	481.6	862.9	4.14	×	×	×	×	×	2.14	11.56
2. Gopalpur	—	49.9	195.0	5.03	4.00	×	×	×	×	×	20.24	10.13
3. Bimlipatam	—	390.1	952.6	341.3	94.27	72.87	44.91	12.66	42.7	175.92	49.66	209.73
4. Lawson's Bay	—	72.3	484.9	942.6	88.17	142.15	124.57	142.54	129.44	89.19	243.60	194.63
5. Vishakapatnam	—	—	—	96.86	132.00	26.52	31.84	28.74	7.43	47.79	11.73	10.64
6. Pudumadaka	—	145.2	43.5	177.06	77.44	12.32	27.51	29.84	29.60	1.40	22.79	58.62
7. Uppada	—	44.8	281.9	154.75	182.68	114.25	90.88	213.78	81.43	58.24	54.00	72.21
8. Kakinada	—	82.8	341.8	221.88	314.83	31.55	5.91	36.66	52.24	72.14	27.47	52.83
9. Sathankuppam	—	1.35	8.3	1.63	0.74	6.04	3.60	7.32	×	×	×	10.94
10. Mypaud	—	12.68	—	—	—	1.92	0.37	0.51	×	×	×	21.50
11. Kothapatnam	—	1.06	3.67	11.62	26.64	17.38	1.31	6.19	×	×	×	2.07
12. Ennore	—	12.5	6.20	2.00	5.77	1.07	2.33	2.13	9.50	10.46	15.91	2.29
13. Triplicane (Madras) ..	—	30.3	7.60	1.90	4.07	1.38	2.52	23.36	25.59	8.95	19.96	6.26
14. Sadras	—	12.00	2.70	5.20	3.62	7.81	1.23	3.52	3.04	3.14	8.17	4.33
15. Cuddalore	—	22.0	10.30	22.00	8.07	101.10	2.60	10.71	18.12	9.60	123.27	5.02
16. Tranqueber	—	—	43.40	97.28	51.16	229.65	23.01	28.16	61.26	43.84	50.09	27.12
17. Akkaraipettai (Negapatnam) ..	—	—	59.60	29.28	—	60.71	25.01	47.62	151.61	—	39.42	23.71
18. Adirampatnam	—	—	50.4	15.83	17.64	11.17	16.34	11.17	1 4.18	9.96	4.08	9.42
19. Nambuthalai (Tondi) ..	—	—	16.6	11.21	29.34	98.01	19.80	55.71	86.99	29.34	22.54	—
20. Tuticorin	—	—	10.44	9.1	15.14	13.47	22.94	17.58	32.81	18.28	20.56	23.83
21. Idindakarai	—	—	14.7	14.1	—	—	—	6.92	14.76	61.39	36.33	38.18
West Coast—												
22. Vizhingam	—	—	65.40	90.83	75.74	106.77	—	128.14	281.68	507.03	319.87	37.94
23. Wadi	—	—	—	87.66	11.11	19.39	—	96.16	138.12	51.00	58.96	10.44
24. Narakkal	—	—	19.35	50.53	—	173.42	—	49.44	42.80	70.08	12.35	155.89
25. Malipuram	—	—	70.39	—	35.75	—	100.09	82.11	100.05	59.75	14.47	150.89
26. Tanur	—	157.8	302.53	174.51	282.53	75.00	230.31	319.87	385.63	2521.50	432.82	663.45
27. Calicut	—	127.2	91.82	52.98	122.35	288.70	150.56	351.49	426.51	1126.41	552.50	301.30
28. Quilandy	—	528.5	185.70	154.42	412.42	59.85	395.43	290.11	356.60	309.25	—	262.62
29. Karwar	—	—	2.06	0.35	×	×	×	×		24.31	364.63	1348.73
30. Vengurla	—	—	13.22	5.5	×	×	×	×	×	38.23	—	30.07
31. Malwan	—	—	26.42	15.43	×	×	×	×	×	—	—	58.66
32. Ratnagiri	—	—	76.17	—	131.2	×	×	×	×	10.54	219.86	239.84
33. Paj	—	—	220.79	231.07	208.4	×	×	×	×	9.51	58.47	433.39
34. Versova (Bombay) ..	—	—	281.06	416.33	—	×	×	×	×	731.94	1535.84	824.61

X—denotes that there was practically no fishing or very little fishing.
— denotes that there was fishing but statistics not available for estimating the landings.

18

L' ORGANISATION DU SERVICE DES PECHES du CAMBODGE

by

Par M. Dom-Savœun*

ABSTRACT

An account is given of the Fisheries Service of Cambodia. Its functions, organization, personnel, budget and objectives are described.

Jusqu'en Mars 1945, la gestion du domaine piscicole du Cambodge était entre les mains du Protectorat du Cambodge. Les Autorités Cambodgiennes n'étaient chargées que de la perception des taxes et de la surveillance des exploitations.

Ce n'est qu'a partir de cette date que le Gouvernement Cambodgien a commencé á gérer lui-même son propre domaine. C'est le Ministère des Finances et les Gouverneurs Chefs de province qui prennent en charge cette gestion.

Néanmoins notre domaine piscicole étant trés vaste, et faute de personnel compétent, cette gestion est limitée ā des actes restreints purement administratifs. L'ignorance générale des dirigeants dans ce domaine, l'abus des pêcheur, la fraude ont contribué à provoquer une baisse progressive de nos rendements annuels. Aussi le Gouvernement Royal a-t-il trouvé nécessaire de créer un Service des Pêches charge de sauvegarder cette richesse en perdition de facon à pouvoir en tirer un bénefice constant sans pour cela entamer le capital.

Le Service des Pêches du Cambodge a vu le jour à partir de Juin 1949.

Il est dirigé par le Chef du Service des Eaux & Forêts lui-même placé sous l'autorité du Ministère de l'Agriculture et de l'Elevage.

ATTRIBUTIONS

Ses attributions actuelles sont encore limitées aux actes ci-après:

1°.—assurer l'application des mesures prises en vue de règlementer la pêche,

2°.—maintenir la richesse ichtyologique des eaux du Royaume par tous les moyens appropriés et notamment la conservation de la forêt inondée, indispensable à la régéneration et à l'alimentation du poisson, la surveillance des réserves interdites à la pêche,

3°.—étudier les engins et les procédés de pêche ainsi que la faune et la flore du réseau hydrographique du Cambodge,

4°.—contrôler sur le terrain la délimitation des lots de pêche,

5°.—fournir au Ministère des Finances tous les renseignements utiles au sujet :

—des limites et dimensions à donner aux lots affermés,

—des clauses techniques à prévoir aux cahiers des charges relatifs aux adjudications des pêcheries,

—du rendement annuel des lots de pêche et des profits réalisés par les pêcheurs,

6°.—assurer, le cas échéant, l'exploitation pour le compte de l'Etat des lots de pêche dont l'affermage n'aurait pas donnè des résultats satisfaisants.

ORGANISATION ACTUELLE

(1°).—Domaine.—

Le domaine piscicole du Cambodge est divisé en quatre zones :

1.—*le domaine libre* où la pêche est autorisée pour tout le monde pendant la période d'ouverture de la pêche,

2.—*le domaine affermé* (ou domaine réservé) ou le fermier seul a le droit d'exploitation pendant la saison des pêches fixée par un cahier des charges spécial,

3.—*le domaine interdit* oú la pêche, même familiale, est interdite pendant toute l'année,

4.—enfin la *forêt inondée*, qui fait partie du domaine affermé et du domaine interdit.

(2°).—Division du Service.

Le Service des Pêches comprend une Inspection Technique des Pêches, chargée spécialement des questions techniques, de la direction des travaux et du controle des crédits intéressant des travaux.

* Chef du Cantonnement des Pêches de Phnom-Penh.

L'Inspection Technique des Pêches est divisée en deux Cantonnements qui relèvent directement de l'autorité du Chef du Service des Eaux, Forêts, Chasses & Pêches. Le Cantonnement des Pêches des Lacs, comprenant cinq divisions des Pêches, englobe toutes les régions du Grand-Lac et de ses affluents, tandis que le Cantonnement des Pêches de Phnom-Penh, ayant quatre divisions, s'étend sur tout le Mékong, le Bassac, le Tonlé-Sap et les réseaux hydrographiques des arriére-berges.

PERSONNEL

En ce qui concerne le personnel, le Cambodge manque encore de techniciens spécialistes pour la pêche.

En attendant de pouvoir les former, ce dont le Gouvernement se préoccupe actuellement, tous les postes existants sont confiés á des Contrôleurs des Eaux et Forêts et à des gardes journaliers dont le rôle est limité à la répression des fraudes et à l'application des réglements en vigueur.

Un cours de formation de Contrôleurs des Pêches sera envisagé à Phnom-Penh dans le courant de 1952, en vue de pourvoir le Service de personnel specialisé. Ces futurs Contrôleurs pourront ensuite faire des stages de perfectionnement professionnel dans les différents pays où existeront des cours organisés à cet effet par la FAO.

BUDGET

Le Service National des Pêches du Cambodge reste entièrement à organiser et son équipement en bâtiments, personnel et matériel pourront occasionner des dépenses trés élevées. Comme la plupart de ces dépenses seront vite amortissables et comme d'autre part le Service est destiné à faire rentrer d'énormes recettes au Budget, le Gouvernement s'efforcera de consacrer les crédits nécessaires ā l'ozganisation de ce service dans sa forme définitive, ce qui nécessitera des dépenses annuelles de l'ordre de deux à trois millions de piastres au minimum

OBJECTIFS—PROJET

A l'état oú il est actuellement, le Service National des Pêches du Cambodge est incapable de rendre le service qu'on doit attendre de lui.

Le but à atteindre sera de diviser ce Service en deux branches intimement liées l'une à l'autre :

1°.—une branche technique dotée de personnel qualifié qui s'occupera des études techniques tendant :

—à la mise au point de la réglementation,

—à la reconnaissance et á la delimitation minutieuse du domaine piscicole,

—au maintien et à l'amélioration de la productivité des eaux,

—à la connaisannce approfondie des engins employés et de leur rendement,

—à l'utilisation rationnelle des produits de péche,

—enfin aux methodes d'exploitations modernes de la pêche et de ses produits.

2°.—une branche de gestion, chargée de gérer ce domaine suivant les méthodes techniques mises sur pied et de mettre en application les résultats de recherches obtenus par la branche technique précitée.

Le Gouvernement Royal du Cambodge est en train d'étudier la mise sur pied à Phnom-Penh d'un Service Technique local pour lequel il fera certainement appel à des techniciens compétents qui seront en même temps les formateurs des futurs agents des Peches du Cambodge.

Quant à la gestion, le probleme sera plus facilement résolu, car il est tout à fait normal que le jour où nous aurons un personnel suffisant et compétent à notre disposition, le Gouvernement nous laissera entiérement cette charge, comme il l'a fait pour la gestion du domaine forestier.

19

WORKING OF FISHERIES PROGRAMMES BY MEMBER COUNTRIES OF THE INDO-PACIFIC FISHERIES COUNCIL

by

Dr. H. Srinivasa Rao *

The aim of integrated fishery programmes over such a large global area as the Indo-Pacific region would appear to be the attainment of a uniform standard of development over the entire area which, for obvious zoo-geographical and technical reasons, has been constituted into a distinct unit. The preliminary Reports of the F.A.O. Regional Representative (Fisheries) based on *ad hoc* surveys of the countries included in the Region indicate a clear unbalance in the development of the various areas of the Region and that the success of developmental schemes would largely depend upon the action which Governments are prepared to take in implementing them. This action in many cases would presumably be determined to a large extent by the necessary funds being voted for the purpose and by the strength and competence of technical personnel actually available for putting into effect schemes of development. Member Governments of the I. P. F. Council are no doubt grateful to this body of experts for advice on technical matters and try to do their best with the resources available to them, but the question arises as to how far the best possible efforts of the Member Governments would go to help the Council's programme of overall development in the entire region under their jurisdiction. The Reports referred to above seem to reveal a state of technical deficiencies in the countries of the Region which, in many cases, render the starting point from which the deficiencies can be made good extremely difficult to determine. More often it is revealed that there are many starting points from which simultaneous action would be necessary, if any tangible results are to be achieved for the benefit of the countries concerned and of the Region as a whole. It is true that the function of the Council is mainly advisory, but how long can it continue to function effectively if the initial programmes recommended by it remain unfulfilled in the majority of the countries constituting the Council, either for want of finances or for lack of adequate technical assistance? If the object of the Council is to promote a certain uniform degree of development of Fisheries in the Region, it would be very important for the Council, at its meetings not only to take stock of the technical organisation available in each Member Country, but also to consider how best the deficiencies in under-developed countries can be overcome to implement agreed programmes of work. It should, for instance, be possible for the Council to indicate in consultation with the delegations of Member Countries concerned, what minimum staff, equipment and funds would be required to put through a programme of work say, in Planktology, Hydrology or Biology, which would help the Council in its objective of overall development and to plan for the whole region in the following year so that Member Countries will advance together instead of the weaker ones retarding the progress of the stronger and thus of the entire Region. It is obvious that in the subject of Fisheries, the Council is dealing with organisms which move constantly to and fro across political boundaries and complicate matters. For example, when the Council is planning the study of the Tunas or Mackerel or Herring it is dealing not with local but widespread interacting physical and biological phenomena which take the fishery problems on to an international plane and render simultaneous and unified action at different geographical points urgent and imperative. The Council should, in my opinion, determine the minimum extent of this unified action and see that this action is initiated by Member Countries within a prescribed period which may vary from country to country depending upon the equipment and staff available to each.

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Section III

SYMPOSIUM PAPERS

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1

A PROVISIONAL SURVEY OF THE INTRODUCTION AND TRANSPLANTATION OF FISH THROUGHOUT THE INDO-PACIFIC REGION

by

W. H. Schuster*

ABSTRACT

An account is given of the spread of fish over the Indo-Pacific Region by human action. The records are divided into :

(*a*) The scattering in historic times of the Asian varieties of *Cyprinus carpio*, *Carassius auratus*, *Ophicephalus striatus* and *Rasbora lateristriata* all over the region.

(*b*) The planned transplantation of fish between parts of the region for cultural purposes in recent time, including 18 species and 48 separate records.

(*c*) The introduction of foreign species into the region, subdivided into the importation of fish for cultural purposes (9 species) and the introduction of larvicidal fishes (3 species).

A description is given of the environmental requirements of the 20 species of fish which are mainly used for transplantation and their merits are discussed. Then follows an outline of the types of water, suitable for stocking with transplanted fish. The survey closes with a discussion of the advantages and disadvantages connected with transplantation work and a warning against the possibility of the spreading of diseases and pests by uncontrolled transplantations.

S.Y. Lin mentioned in his paper on fish-culture in China the interesting fact that common carp was cultivated in ponds five hundred years before Christ, and if we believe the reports of zoogeographers then the European races of carp as well as those reared at present in the Far East come from the stock which has been domesticated in China about two thousand years ago.

Two peculiarities seem to be the reason why the ancient Chinese showed special interest in fish-culture. Their contemplative conception of life gave them a predilection for keeping ornamental fish in miniature ponds and, being Epicureans, they preferred live fish to dead ones for culinary use. In this manner Chinese people became familiar with the ways of fish at an early date and wherever they went with their ships, carps were taken along to be presented as a symbolic gift to business friends.

A similar process may have taken place with *Ophicephalus striatus* Bl. This labyrinthic fish is often kept alive for a considerable time by Javanese fishermen and transported over long distances. At present it is even shipped alive in sailboats from Bandjermasin in South Borneo to the markets in Singapore. Its occurrence as the single species of a large family in Celebes and some of the Lesser Sunda Islands is possibly due to unintentional transplantation in historical times. Weber and de Beaufort's statement that it was introduced to the Hawaiian Arch. points in the same direction. Another biological peculiarity, the occurrence of *Rasbora lateristriata* (Blkr.) as the only Cyprinid east of the Wallace line, may be explained by the fact that this hardy species is often kept as a pet in fresh-water tanks on ships by Javanese sailors. No proof can be given that *Ophicephalus* and *Rasbora* have indeed spread in the manner described, but to everybody familiar with the ways of Indonesian fishermen, the explanation will appear plausible. In the case of carp, we may assure that the introduced varieties ran wild after some time. Fish culturists used the local stocks to obtain material for rearing in ponds and, when cultural activities reached a higher level, the breeds developed into real " noble races." When considering the origin of the *Galician* or *Bohemian* race of common carp in Central Europe and that of *Si Njonja* or *Kantjera domas* in Indonesia, one will agree that here the same process has taken place in two geographically widely-separated areas.

When considering the biological factors which made the wide distribution of carp possible we find *Cyprinus carpio* with characteristics which are rarely combined in a single sort of fish. Being greatly adaptive to climatological conditions, prolific, omnivorous and modest in its need for oxygen, *Cyprinus* possesses those qualities which may be regarded as a " standard equipment " of vagrant, non-predacious sorts of fish. *Carassius*, *Osphronemus*, *Trichogaster*, *Tilapia*—all widely-spread species—fit easily into this scheme.

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Cultural activities resulted also in a wide spreading of the species involved. Wherever bodies of water, suitable for the cultivation of fish were present, fry of domesticated species were brought there by traders or, in more recent times, by fisheries workers. Temple and monastery ponds may have been rearing places for fish in early times, but also the freshwater tanks, which can be found almost everywhere in the area, can be regarded as precursors of modern fish ponds. Even small domestic tanks become today—as they did in former days—naturally populated with minute fish, and it is obvious that the stocking of these tanks with selected fry, caught in rivers or lakes, was the most plausible beginning of the culture of freshwater fishes. When a certain sort became well-known for its rapid growth or fine taste, the fry were transported over increasingly longer distances to stock the tanks. The transplantation of *Puntius orphoides* C. V. from rivers in West Java to " situs " i.e. tanks, is an example of such a development in modern times. Fish-culture in this way seems to be one of the reasons why some species have become widely spread in the area and, since by these transplantations little attention was paid to the natural ranges of distribution, 500 to 800 years of fish-culture may have contributed largely to zoogeographical changes in the region.

The most obvious of the " planned " transplantations are those of the Chinese carps *Ctenopharyngodon idellus* (C.V.) *Cirrhina molitorella* (C.V.), *Aristichthys nobilis* (Rich.) and *Hypophthalmichthys molitrix* (C.V.) along the East and South Coasts of Asia. Wherever Chinese people settled, they started to construct ponds and began to rear the varieties of fish well-known from their homeland but, since no technique could be developed to induce those species to spawn in their new environments, no bionomic spreading followed the transplantations.

In a similar way *Osphronemus goramy* Lac. was spread by Javanese colonists all over the archipelago and was brought to far-away countries such as Ceylon, Egypt or Sicily by people interested in fish-culture. Since goramy was able to adapt itself to local conditions, it became a popular fish in many countries where it spawned freely in rivers and lakes.

Independent of the culture of fresh-water fishes, the rearing of marine fish has been an indigenous industry in the Indo-Pacific area since time immemorial. We know from Roman classical literature that Muraena's were kept in marine fish ponds in Italy in Nero's time, but we can also mention the fact that, in accordance with old Javanese law books, *Chanos* was cultivated in salt-water ponds in Java long before the first Europeans came to the Far East. Areas, purposely embanked for the production of solar salt may have been the first marine fish ponds in East Asia, since the reservoirs from which salt fields are filled with sea-water automatically become natural fish ponds in the wet season ; however, no historian has told us about these early stages of the tambak industry. The transition from the rearing of miscellaneous fish to the planned cultivation of *Chanos* and *Puntius* was so gradual that no correct data can be given about the beginning of the transplantation of fry. It is known that already in 1400 A.D. a trade in *Chanos* fry existed in Java.

When recent intentional transplantations are taken into consideration, we find that even transitions between the fresh-water and the salt-water regions have taken place. In Java *Puntius javanicus* Blkr. was brought down to the coast to be cultivated in brackish-water ponds ; in Ceylon *Etroplus suratensis* (Bl.) was brought inland to be reared in tanks, and in India real marine species such as *Lates calcarifer* Bl., *Lutjanus argentimaculatus* (Forsk.) and *Megalops cyprinoides* (Brous.) were " acclimatized " and made suitable for the stocking of inland waters. That means that ecological as well as zoogeographical border lines become obscure when fisheries biologists succeed in populating waters with the varieties of fish which, for economic or biological reasons, are regarded as useful in a certain type of water.

Another group of transplantations of fish consists of those by which certain varieties have been unintentionally spread in recent times to areas outside their original region of distribution. In this connection " unintentionally " stands only for " not intended by fisheries biologists ", since modern means of transportation make it possible for any amateur to take live fish to places where professionals would never take them. The introduction of *Clarias batrachus* (L.) and *Trichogaster trichopterus* (Pall) into the waters of Celebes and the introduction of *Mollienisia latipinna* Le Sueur from Hawaii into the Philippines are examples of transactions of this kind.

The compiler of this survey does not flatter himself in the belief that the greater part of the transplantations, effected in the course of time, have come to his knowledge. It is his intention only to draw attention to this important subject, and to provide for a scheme into which further information can easily be fitted.

The available body of facts enabled the writer to compile the following provisional list :

A. *Unintentional spreading of fish in historical time*

Species	from	to	in
Cyprinus carpio L.	China	Countries of the continent of Asia, Java, Sumatra	
Carassius auratus L.	China	Countries of the continent of Asia, Java	
Ophicephalus striatus Bl.	Java, Borneo	Celebes, Lesser Sunda Islands, Moluccas, Hawaii	
Rasbora lateristriata (Blkr.)	Java	Lesser Sunda Islands	

B. *Planned transplantation for cultural purposes in recent time*

Species	from	to	in
Cyprinus carpio L.	Java	Celebes	1895
		Sumatra, Borneo	1903
		Flores	1932
		Bali, Lombok	1941
	China	Philippines	1915
	China	Thailand, Indo-China	?
		Malaya, Ceylon, India	?
Ctenopharyngodon idellus (C. V.)	China	Thailand, Malaya	?
		Sumatra	1915
		Java, Ceylon	1949
Cirrhina molitorella (C. V.)	China	Thailand, Malaya	?
		Sumatra	1915
Hypophthalmichthys molitrix (C. V.)	China	Thailand, Malaya	?
		Ceylon	1948
Aristichthys nobilis (Rich.)	China	Thailand, Malaya	?
		Ceylon	1948
Mylopharyngodon aetiops (Bas).	China	Indo-China, Thailand	?
Carassius auratus L.	China	Indo-China, Thailand	?
Catla catla H.	India	Ceylon	1942
Puntius javanicus (Blkr.)	Java	Celebes	1930
		Borneo	1949
Osteochilus hasselti (C. V.)	Java	Sumatra	1903
		Moluccas	1929
		Celebes	1937
		Bali, Lombok	1941
Osphronemus goramy Lac.	Java	Thailand, India	?
		Celebes	1903
		Bali, Lombok	1941
		Philippines	1927
		Ceylon	? 1890
Helostoma temmincki (C. V.)	Borneo	Celebes	1925
	Java	Bali, Lombok	1941
	Thailand	Philippines	1948
Trichogaster pectoralis (Regan)	Thailand	Malaya	1921
	Java	Java	1934
		Celebes	1937
		Borneo	1940
		Bali, Lombok	1941
		Moluccas	1949
		Flores	1949
Tilapia mossambica Peters	Java	Bali, Lombok	1941
		Celebes	1944
		Moluccas	1949
Aplocheilus panchax (H. B.)	Java	Bali, Lombok	1935
		Celebes	1938
Dermogenys pusillus v. Hass.	Java	Bali	1935
Ctenops vittatus (C. V.)	Java	Bali	1935
Mollienisia latipinna Le Sueur	Hawaii	Philippines	?

C. *Introduction of fish, not autochthonous to the Indo-Pacific Region*

1. Cultivated Species

Species	from	to	in
Cyprinus carpio L.	? Europe	Australia	
	? Europe	Japan	
	? Europe	India	
	Europe	Indonesia	1927
Tinca vulgaris Cuv.	Europe	Indonesia	1929
Carpio collari (Heckel)	Europe	Indonesia	1929
Trutta (*Salmo*) *fario* L.	? Europe	Australia	
		Tasmania	
		Japan	
		India	
Trutta (*Salmo*) *irideus* Gibb.	? N. America	Japan	
		Australia	
	Australia	New Guinea	1949
	Europe	Indonesia	1929
	? Europe	India	
Salmo gairdnerii Wal.	N. America	Japan	
	? N. America	Ceylon	
Salvelinus fontinalis Mit.	N. America	Japan	
		Korea	
Huro salmoides Lac.	N. America	Philippines	1907
Haustor catus ?	N. America	Philippines	1935

2. Larvicidal Species

Species	from	to	in
Lebistes reticulatus (Peters)	Europe	Java	1920
	N. America	New Guinea	1943
		India	1946
		Ceylon	
		Philippines	
		Malaya	
		Borneo	1928
Gambusia affinis (B. G.)	N. America	Hawaii	1905
		Philippines	
	Europe	Indonesia	1920
		India	
		Malaya	
Mollienisia latipinna Le S.	N. America	Hawaii	1905

The introduction of fish, not autochthonous to the region, can be subdivided into the importation of domesticated species for cultural purposes and the intentional distribution of foreign species for special motives.

Of the fishes imported to be cultivated in impounded waters, in the first place, the European varieties of *Cyprinus carpio* should be mentioned. More than one country in the region attempted to obtain by importation a race of carp superior to the local varieties, but it seems that they all feel that they have come away with a flea in the ear. Indonesia made an attempt with the *Galician* and the *Bohemian* race, Japan took the *Aischgründer*, India used a Mirrorcarp of unknown race and all these carps propagated and became mixed with the local stock of carp, but enthusiastic reports about higher yields or other advantages were not forthcoming. It seems that European carps quickly lose their squat shape, whilst their mortality when cultivated under tropical or subtropical climatic conditions rises above that of the Asian races.

Much more successful was the introduction of *Salmonids* into the region. Australia, New Zealand, Tasmania, Japan, India and Ceylon all imported

trout years ago, and at present possess a stock of Salmonides which can be regarded as a valuable addition to the indigenous stock of fish.

To the second group of introduced fish belong the varieties which were brought to the Indo-Pacific region for larvicidal purposes. *Lebistes*, *Gambusia Mollienisia* and *Aplocheilus* became widely spread throughout the area because not only fishery workers, but hygienists also, took part in the distribution. War conditions supported the spreading of the "millions", as they went with the army to every place where a medical post was set up, to be released in the waters in the neighbourhood of the station.

In those cases where the origin of the fish is uncertain it is hardly possible to make a clear distinction between transplantation and introduction. In the short period during which organized fisheries-control existed in Indonesia, four examples of the appearance of a species of fish "in terra nova" were observed.

Most obvious was the occurrence of *Tilapia mossambica* Peters in 1939 when five specimens, caught in a lagoon of a small river in Java, became the progenitors of a fresh- and brackish-water stock which at present yields thousands of tons of fish a year. Another example is the occurrence in West Java in 1948 of *Carassius auratus* L. in a variety much resembling the "Crucian carp" of European or Japanese waters. Earlier, in 1925, *Trichogaster trichopterus* (Pall.) suddenly appeared in lakes in North Celebes ; no explanation could be given as to how it got there.

Experienced hydrobiologists do not give much credit to the story of fish eggs being transferred by waterfowls, and so man with his queer habits and character will in most cases have to be regarded as the originator of those "inexplicable" happenings. In 1939 *Clarias batrachus* (L.), a predator which causes harm in stocked waters by feeding on spawn, appeared suddenly in rivers in South Celebes. Since *Clarias*, a Siluroid, does not naturally occur east of the Wallace line, the interesting question arose as to how it got there. Investigation showed that a foreman of a rural waterboard, who went on leave to Java, transported some specimens alive over a distance of more than 900 miles because, as he said, he was fond of *Clarias* which he remembered from his childhood as a good fish to be caught with hook and line. This example, given *in extenso*, serves to illustrate what modern means of transportation can do. Clarias could not be expelled from Celebes again and there is a 20,000 tons inland fishery at stake. Things like these will happen everywhere in the region and the only means of controlling them is by a fisheries-service which is ahead of developments and is prepared to act quickly when it comes to the point.

Fish belong to Fisheries and all matters concerned with fish should be dealt with by fisheries biologists. The introduction of *Lebistes reticulatus* into Java and that of *Mollienisia latipinna* into Hawaii and the Philippines are striking examples of the fact that even scientists, unacquainted with limnological problems, may cause grave harm when trespassing on somebody else's premises. Disappointing or even negative results have been attained, and things like that will happen again whenever operations are carried out without careful calculation of the whole range of consequences. But lack of experience or the absence of printed information must never lead to a haughty rejection of all introduction or transplantation work ; but unfortunately such a tendency is noticeable today.

In Indonesia an absolutely new fishery, yielding 15,000 tons of fish annually, could be built up in five years' time by transplantation of two species of fish into a new area. The introduction of *Tilapia* resulted in the production of another 5,000 tons of fish a year in Java alone. These examples are ample proof that great advantages can be achieved with work of this kind, and since the practical issues of transplantations and introductions are the only available guide for future work, the recording of all operations is a matter of the utmost importance.

We are anxious to increase the production of our waters by managing them in the most efficient way and that includes, among other measures, the stocking or restocking with fish which under prevailing conditions are able to yield better than the original stock. We therefore want to have at our disposal such a number of species and varieties that selection of a suitable sort of fish for every type of water will be possible. Workers in the region, as well as the biologists outside, want to know how the species and varieties involved react when transplanted from open water to ponds, what they do when reared in confined waters and how they behave when used for rough release. This is what we want but we must agree that little has been done to achieve this end.

Every country in the Indo-Pacific Region possesses at present a number of species and varieties which have been investigated and tested to some degree but it is difficult to judge their suitability, as hardly any reliable comparative work has been done. Ecological conditions show little difference in the equatorial zone of the region ; however, nobody can say at present which species of plankton and detritus feeders, herbivores, carnivores or omnivores reared there can be regarded as superior in production or staying power.

The compiler of this survey tried to draw up a list of the known properties of the species commonly used for transplantation. The records in this list are still far from complete and some species had to be omitted because of lack of reliable data, but it will have to suffice until more reliable information becomes available.

A. Omnivores

1. *Cyprinus carpio* L., Asian varieties.

Feeds on : Chironomidae, Ephemeridae, Crustacea, Mollusca, Trichoptera and many kinds of farinaceous feeding-stuffs.

Suitable for cultivation under tropical conditions between 100 and 1000 m above sea-level. Resistant to low oxygen tension and restricted space. Spawns in captivity. Natural annual production in ponds up to 600 kg per ha. Suitable for rearing in rice fields and impounded waters, which dry out regularly. Not suitable for release in waters where it is difficult to remove all fish. Mediocre food-fish.

2. *Cyprinus carpio* L., European varieties.

Feeds on : Chironomidae, Ephemeridae, Tubificidae, Crustacea, Mollusca and many kinds of farinaceous feeding-stuffs.

Suitable for cultivation under tropical conditions from 500 to 1000 m above sea-level. Spawns in captivity. Natural annual production about 500 kg per ha. Not suited for cultivation outside ponds. Good food-fish.

3. *Carassius auratus* (L.)

Feeds on ; Chironomidae, Tubificidae, Crustacea.

Suitable for cultivation under tropical conditions between 200 and 1000 m above sea-level. Spawns in captivity. Natural annual productivity about 400 kg per ha. Not suited for cultivation outside ponds. Only advantage over *Cyprinus carpio* : firmer flesh.

4. *Osphronemus goramy* Lac.

Feeds on : soft leaves of aquatic and land plants, fruits, insects, and many kinds of vegetable and animal feeding-stuffs.

Suitable for cultivation under tropical conditions to 800 m above sea-level. Resistant to very low oxygen tension and restricted space. Spawns in captivity. Natural annual production in ponds approaches 200 kg per ha. Suitable for rough release in lakes and rivers. Excellent food-fish.

5. *Tilapia mossambica* Peters.

Feeds on : Chlorophyceae, Cyanophyceae, Conjugatae, Characeae, Diatomeae, Crustacea, detritus.

Suitable for cultivation under tropical conditions to 1000 m above sea-level. Resistant to low oxygen tension and restricted space. Spawns in captivity. Natural annual production some 500 kg per ha. Suitable for cultivation in ponds, impounded waters and for rough release in lakes. Especially important for stocking swamps or marshes which dry up annually. Adapts itself easily to brackish-water conditions. Good food-fish.

6. *Etroplus suratensis* (Bl.)

Feeds on : Cyanophyceae, Chlorophyceae, Copepoda, Cladocera, Ostracoda.

Suitable for cultivation under tropical conditions. Spawns in captivity.

Suitable for cultivation in ponds, impounded waters and for rough release in lakes. Is a brackish-water species which adapts itself easily to fresh-water. Mediocre food-fish.

7. *Cirrhina mrigala* (C.V.)

Feeds on : Cyanophyceae, Diatomeae, Mollusca, Vermes, " scavenger ".

Suitable for cultivation under tropical conditions. Does not spawn in captivity. Natural production some 300 kg per ha. Often cultivated in combination with other species. Suitable for cultivation in ponds, impounded waters and for rough release in rivers. Good food-fish.

B. Plankton and Detritus Feeders

1. *Trichogaster pectoralis* (Pall.)

Feeds on : Diatomeae, Cyanophyceae, Flagellata, Ciliata, Rotatoria, Cladocera, Copepoda, detritus.

Suitable for cultivation under tropical conditions to 800 m above sea-level. Resistant to low oxygen tension. Poor yields when cultivated in ponds. Spawns in captivity. Suitable for rearing in rice fields and for rough release in marshes and swamps. Mediocre food-fish, suitable for processing as dried fish.

2. *Helostoma temmincki* (C.V.)

Feeds on : Diatomeae, Cyanophyceae, Flagellata, vegetable detritus.

Suitable for cultivation under tropical conditions to 800 m above sea-level. Resistant to low oxygen tension. Often cultivated in ponds in combination with other species. Natural annual production about 500 kg per ha. Spawns in captivity. Suitable

for rough release in marshes and slow running rivers. Good food-fish, suitable for processing as dried fish.

3. *Aristichthys nobilis* (Rich.)

Feeds on: Flagellata, Diatomeae, Cyanophyceae, Ciliata, Rotatoria, detritus.

Suitable for cultivation under tropical and subtropical conditions. Resistant to low oxygen tension and restricted space. Often cultivated in combination with other species. Annual production in manured ponds about 1000 kg per ha. Does not spawn in captivity. Not suitable for rough release. Excellent food-fish.

4. *Hypophthalmichthys molitrix* (C.V.)

Feeds on: Flagellata, Diatomeae, Cyanophyceae Ciliata, Rotatoria, detritus.

Suitable for cultivation under tropical and subtropical conditions. Resistant to low oxygen tension and restricted space. Often cultivated in combination with other species. Annual production in manured ponds about 1,000 kg per ha. Does not spawn in captivity. Not suitable for rough release. Excellent food-fish.

C. Herbivores

1. *Puntius javanicus* (Blkr.)

Feeds on: Characeae, Ceratophyllaceae, Polygonaceae, Lemnaceae, Najadaceae, Chlorophyceae, Conjugatae, Gramineae.

Suitable for cultivation under tropical conditions to 800 m above sea-level. Natural annual production in ponds some 500 kg per ha. Suitable in restricted measure for rearing in rice fields and ponds with a salinity up to 8 per mille. Suited for rough release in swamps and marshes with a dense, submerged vegetation. Mediocre food-fish, suitable for processing as dried fish.

2. *Ctenopharyngodon idellus* (C.V.)

Feeds on: aquatic plants and leaves of land plants.

Suitable for cultivation under tropical and subtropical conditions. Resistant to low oxygen tension and restricted space. Often cultivated in combination with other species. Annual production approaches 1000 kg per ha when additional feeding is given. Does not spawn in captivity. Not suitable for cultivation outside ponds or enclosed waters. Excellent food-fish.

3. *Labeo calbasu* (H.B.)

Feeds on: " Higher-organized, aquatic plants and plankton ".

Suitable for cultivation under tropical conditions. Does not spawn in captivity. Natural annual production about 300 kg per ha. Often cultivated in combination with other species. Suitable for cultivation in ponds, impounded water and rough release in rivers. Good food-fish.

4. *Labeo rohita* (H.B.)

Feeds on: " Higher-organized, aquatic plants and plankton ".

Suitable for cultivation under tropical conditions. Does not spawn in captivity. Natural annual production some 400 kg per ha. Often cultivated in combination with other species. Suitable for cultivation in ponds, impounded waters and for rough release in rivers. Excellent food-fish.

5. *Catla catla* (H.B.)

Feeds on: " Higher-organized, aquatic plants and plankton ".

Suitable for cultivation under tropical conditions. Does not spawn in captivity. Natural annual production about 500 kg per ha. Often reared in combination with other species. Suitable for cultivation in ponds and rough release in rivers. Excellent food-fish.

6. *Chanos chanos* (Forskal)

Feeds on: Cyanophyceae, soft parts of Chlorophyceae, Conjugatae and Characeae, Diatomeae, detritus, conditional: Crustacea, Protozoa, Vermes.

Suitable for cultivation under tropical conditions. Does not spawn in captivity. Natural annual production about 500 kg per ha. Marine species which adapts itself easily to fresh-water conditions. Suitable for cultivation in ponds and impounded waters. Excellent food-fish.

D. Carnivores

1. *Salmo (Trutta) fario* L.

Feeds on: " air-food ", Gammaridae, Chironomidae, Ephemeridae, Trichoptera, fry of fish.

Suitable for cultivation under tropical conditions at 1000 m above sea-level. Suitable for rough release in streams. Artificial fertilization of eggs recommended. Excellent food-fish.

2. *Salmo* (*Trutta*) *irideus* Gibb.

Feeds on: Cyclopidae, Gammaridae, Chironomidae, Ephemeridae, Tubificidae, Trichoptera and many kinds of animal food-stuffs.

Suitable for cultivation under tropical conditions at 1000 m above sea-level. Suitable for cultivation in ponds. Annual production some 200 kg per ha. Suitable for rough release in streams. Artificial fertilization of eggs recommendable. Excellent food-fish.

With this range of fish at our disposal we are able to provide for proper technical stocking of all types of water we meet in the region. Of course, we are not absolutely sure that the species recorded are the best available in the area but in practice those mentioned have proved to be of good use.

To decide whether and with which sorts of fish a water should be stocked, we may follow the classical rules indicated in Wundsch " Die Arbeitsmethoden der Fischereibiologie ". However, the methods developed in Europe call for a trained staff of field-workers and since nowhere in the region is there a team of experienced limnologists at work, conditions at present often necessitate the application of simpler techniques.

In actual practice the first step to be taken is to draw up an inventory of the species of fish occurring in the water in question. Then the position of each important species in the biocoenose of the water has to be established on the basis of the feeding and spawning-habits. The next thing is to investigate the amount of fish-food present in the water which is not used by the natural stock of fish, and that is a point where exact methods let us down.

The primary food-resources of our inland waters consist of the aquatic microfauna and flora, the higher organized water-plants and the refuse matter which a water receives from the shore-vegetation. This primary food may be completely or partly consumed by fishes directly suitable for human consumption, but, on the other hand, primary food is often used by small or inferior species which have to serve as food to predators first to achieve economical value.

When a system of water in a tropical area is left to its own resources for a long time, a prevalence of predacious species will usually be the result. A decision about the measures to be taken to develop such a water depends on the following questions:

Is the full amount of vegetable fish-food used up by the autochthonous primary feeders or not ?

Will the density of predators permit of the introduction of a new, prolific species of primary feeders ?

Is it rational to maintain a preponderant carnivorous stock of fish when we assume that 10 to 40 pounds of primary feeders are necessary to yield one pound of flesh of predators ?

Will it be possible to reduce the density of predators by directing the capture-activities, for instance by the distribution of special gear or the award of premiums on the capture of undesirable species ?

The fisheries biologist in the Indo-Pacific Region depends to a high degree on his own insight and on his knowledge of local circumstances in deciding these questions. To be able to decide whether a new species should be introduced, a reasonable knowledge of the ecological conditions as well as a clear outline of the possibilities is necessary.

A brief outline of the different types of water may be of some use to indicate the waters into which fish can be introduced.

1. *Ponds or pond-like waters* as domestic fresh-water tanks and small irrigation tanks which, like real ponds, can be drained. Since removal of predators and cleaning and tilling of the soil is possible, every type of fish culture is possible in waters of this type in accordance with local conditions. The desirability of the introduction of new species depends on the yielding capacity of the indigenous species.

2. *Swamps*, *marshes* and *wet rice fields*, flooded during 6 to 10 months and dry during the rest of the year. Often very productive waters with a dense aquatic vegetation, but due to their intermittent character lacking the capacity to develop naturally an economically important stock of fish. Annual stocking with seed or full-grown specimens of quickly spawning species is advisable. Recommendable: *Cyprinus carpio* and *Trichogaster pectoralis* for rice fields, *Tilapia mossambica*, *Trichogaster pectoralis* and *Puntius javanicus* for swamps and marshes. Under special circumstances *Etroplus suratensis* and *Chanos chanos* may also be used.

3. *Lakes*, *large irrigation tanks* and *perennial swamps*. When situated west of the Wallace line, these waters commonly bear a natural fish-population, mainly consisting of *Siluroidae*, *Cyprinidae* and *Labyrinthici*. Seldom duner-populated. Development depends on the possibility of suppressing predators. The sorts of fish to be used for introduction, when predators are under control, must be chosen in accordance with food-resources. Water east of the Wallace line, usually lack a varied, natural stock of fish and are therefore of great promise for cultural purposes.

4. *Rivers, streams* and *deltaic waters.* West of the Wallace line these waters are usually densely populated with *Siluroidae* and *Cyprinidae.* The capacity depends on the soil conditions in the watersheds and the density of the shore vegetation. In the slow moving rivers a surplus of plankton and decayed vegetable matter may often be found. Stocking of middle courses with *Osphronemus goramy* and of lower courses and deltaic waters with *Helostoma temmencki* and *Trichogaster pectoralis* can often be successful. Development can be achieved by directing fisheries activities to the suppression of predators and the protection of primary feeders. The riverine waters, east of the Wallace line, are often underpopulated and open to introduction of new species.

A retrospective view of the introductions, which have become an avowed success, shows that relatively little effort is necessary to adapt a well-chosen species to new surroundings. Ten full-grown specimens of *Trichogaster pectoralis,* brought from Malaya to Indonesia in 1930, were sufficient to build up a huge population of this species in Java, Borneo and Celebes. In 1930 a small pot filled with fry of *Puntius javanicus* was shipped to Celebes and now the yield of this fish there amounts to about 15,000 metric tons a year. And finally, the immense stock of *Tilapia mossambica,* now present in the Far East, is descended from the 5 specimens caught in Blitar, East Java in 1939. The thousands of tons of fish, now produced in areas where the involved species were unknown a few years ago, are a clear manifestation that transplantation-work can be of great importance for the development of the fisheries in a certain area.

When the disadvantages which arose in consequence of the intentional or unintentional introduction of fish are taken into consideration, the following can be stated.

Actual harm was caused by the transplantation of predators—the transplantation of *Clarias batrachus* to Celebes can be mentioned as an example. Since no hydrobiologist will give his consent to such inconsiderate action as the transplantation of a prolific predator of low economic value to a new area, an incidental case should not be regarded as a condemnation of transplantation-work generally.

A disadvantageous effect also occurred when *common carp* was introduced into deep lakes. This clever fish withstands all efforts at capture and becomes a competitor for food to better yielding species. It should be borne in mind that *Cyprinus carpio* should be stocked only in waters that are easy to drain or fish.

Another weak point is the intentional spreading of larvicidal species which is still on the programme in many countries. *Lebistes reticulatus* and *Mollienisia latipinna* are causing grave harm now as competitors for food in fresh-water and brackish-water ponds in the area, and the advantages of these species over autochthonous ones are doubtful to say the least of it. It should be clearly recognized that the effect of anti-malarial efforts does not depend only on the voracity of a larvicide species of fish, but also and even to a great extent on the condition of the water in which the mosquitoes breed.

None of the malaria-carrying Anopheles breeds in open water ; they all deposit their eggs in plant-masses or floating debris. Mats of algae and semi-submerged grasses growing in shallow ponds have become notorious for the number of anopheles-larvae which develop there, protected from attack by fish. No larvicidal fish is able to intrude into thick layers of vegetation and the efficiency of anti-malarial measures therefore mainly depends on the degree to which a water is covered with floating vegetation or other materials among which the larvae can shelter. A clean pond can be kept free of larvae by stocking it with about 20 specimens of larvicidal fish per acre, while a water covered with algae or grasses may be stocked without effect with a much greater number of fish.

In concluding this survey a point should be brought up for discussion which deserves our full attention.

The countries of the Indo-Pacific Region have so far been spared disastrous fish diseases. We know *Enteritis* of carps, caused by unsuitable or decayed food ; we know that our fish are infected with protozoa as *Gyrodactylus, Dactylogyrus* and *Ichthyophthirius* ; we know gillrot caused by the fungus *Branchyomyces* and infections with parasitic *Trematodae* and *Nematodae.* We have seen fishes infected with *Argulus, Piscicola* and *Diplostomum* but no infection was ever so widespread that it became an actual danger to the pond industry of a country. But what would happen if *Pseudomonas punctata* for instance, a bacterium well-known from Europe as the originator of the dangerous abdominal hydropsy of Cyprinids found its way to the Far East ? Thousands of acres of rice fields in Indonesia are stocked with carps, and ponds covering hundreds of thousands of acres are to be found all over the region. We just cannot imagine what would happen if really dangerous infectious fish-diseases spread here. The interests involved are immense and international cooperation in defending them is highly necessary. At least one biologist working in the region should be specially trained in recognizing and fighting fish diseases, to act as an

adviser when it comes to the point. Europe with its comparatively small inland fishery has a number of laboratories where highly-skilled techniques have been developed in recognizing and fighting the diseases of cultivated and wild fish. A single specialist for the whole Indo-Pacific Region would surely be no luxury.

All that the common fisheries worker can do at present is to keep an eye on all introductions of fish from outside the area, and to make up his mind as to the isolation measures that will have to be applied. Some places in the area are already heavily fouled with pests and there is absolutely no need to extend the range of spreading. Almost all fish from Singapore are infected with Protozoa and as this place is a junction in international trade in aquarium fish, the possibility that new diseases will come via Singapore is great.

If we venture to make any suggestions for the development of inland fisheries by the introduction and transplantation of fish we should emphasize in the first place the necessity for international cooperation in exchanging information. Planning of introductions or transplantations can only be carried out with reasonable certainty when information is available concerning the yielding capacity of a fish and its suitability for cultural purposes in the country of origin. Gaining of production data and recording of the results of transplantations should be considered of the highest importance in every Fisheries Department.

Another suggestion is that the importation of live fish into a country should be supervised by the local fisheries department which, even in the case of ornamental fish, should decide whether importation may be permitted or not. If each consignment of fruit entering a country can be inspected, surely the same can be done with live fish. We cannot make sure by quick inspection whether a batch of fish is infected with parasites or not, but we can check the importation of Cyprinids and Poecilids which may cause trouble as carriers of bacterial diseases or spread to become competitors for food.

The last point of my survey is the suggestion to take under observation the species which show an inclination to spread. It is quite likely that species, such as *Tilapia* intentionally or unintentionally will spread all over the region and it would be better to be informed about the cultural possibilities under local conditions than to wait until the fish has spontaneously made its entrance.

With these suggestions I should like to conclude my survey, and I hope that the information collected will be a stimulant to the continuation of investigations in this direction.

2

METHODS AND PROBLEMS OF COLLECTING EGGS AND FRY FOR TRANSPLANTATION

by

Herminio R. Rabanal*

ABSTRACT

A brief survey is given of the methods of collecting eggs and fry in this region. Particular attention is paid to methods in use in the Philippines, especially for handling *Chanos chanos*. The problems are discussed and some suggestions made for improvements.

Within recent years, great attention has been focused on the methods employed in the collection of fish eggs and fry in the Indo-Pacific area because of the growing importance of pond fisheries within this region. Collection is being undertaken under very diversified conditions from well-controlled hatcheries and artificially-built ponds down to rivers and lakes and the sea. This results in various methods being used. Another reason for this diversity is found in the width and geographic isolation of the region as a result of which peculiar local practices have developed. The methods appear to be a product of long and slow development arising from necessity and utilizing whatever materials are easily procurable within the different localities. It is important to compile and compare these methods and to note the short-comings and merits of each, with the idea of adopting the best for the general good of the area,

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and possibly to correct any defects that may be noted.

The eggs and fry collected for transplantation work within the region include the following categories :

1. The spawn collected and produced in captivity such as in hatcheries and artificially-built ponds. This is very well exemplified in the common carp, *Cyprinus carpio* Linnaeus, which is almost of general distribution in the region. At least four species of economic carps from India also belong to this group.

2. The natural spawn collected from rivers and lakes. To this group belong several species of carps from China and India.

3. The natural spawn collected from the sea and estuarine waters. The species belonging to this category are treated particularly in this paper. This includes the milkfish of the Philippines, Indonesia and Taiwan ; the grey mullet of China, Indonesia and the Philippines; the jumbo tiger-shrimp of the Philippines and Indonesia and the eel of Japan.

In general, the present method of collecting eggs and fry are beset with problems. Having been developed from simple beginnings they usually lack co-ordinated organization. Also for this reason the gear used is more or less primitive and needs improvement. Conservation of eggs and fry, by improving the methods of catching, storage and handling to minimize mortality losses are important to make it possible to meet future needs and for expansion.

SPECIES INVOLVED

In the Philippines the species of fish fry gathered in commercial scale for purposes of cultivation are mostly confined to those found in the sea and estuarine waters. The most important of these is the milkfish or " bangos, " *Chanos chanos* (Forskal).

The jumbo tiger-shrimp or " sugpo ", *Penaeus monodon* Fabricius, is another important species, the cultivation of which has great commercial possibilities.

Other species of minor importance which are occasionally reared in ponds include the following :

1. The mullets, *Mugil* spp., specially the grey mullet, *Mugil cephalus* Linnaeus.

2. The spade-fish or butter-fish or " kitang ", *Scatophagus argus* Linnaeus.

3. The siganids, Teuthidae *Teuthis* spp.

4. Sea-bass or " apahap ", *Lates calcarifer* (Bloch).

5. Groupers or " lapu-lapu ", *Epinephelus* spp.

6. Blue crab or " alimasag ", *Neptunus pelagicus* (Linnaeus).

7. Swamp crab or "alimange", *Scylla serrata* (Forskal).

METHODS OF COLLECTING FISH FRY

Bangos or milkfish fry

In the Philippines there are at least three principal methods for collecting milkfish fry, namely :

1. Fry trap or " saplad ".
2. Shore seine or " salap ".
3. Dip net and scissor net or " panagap ".

The saplad is a stationary, surface, fry trap. It consists of a catching net and two wings. The net is a sort of half-hoop net opened at one end and closed at the other forming a trough partly immersed in the water. It is about 2 to 3 metres long by 0.5 metre wide and sags medially to form a bag about 0.3 to 0.5 metre deep.

The wings may be made of matting of crushed bamboo, or of wooven palm leaves or even of wooden boards. They are from 2 to 5 metres long by about 0.3 to 0.5 metre wide, with the thickness varying with the material used. These wings are set in V-shaped formation, partly immersed in water and tied to wooden or bamboo poles which are firmly staked at the bottom of the tidal stream. The V-formation faces the sea side of the stream. The apex of the V is not completely closed leaving a gap of about 30 centimetres. From here the open end of the catching net is set. The rest of the net is fixed in place by means of stakes along the sides and at the closed end. During the incoming high tide the planktonic fry which are generally confined in the superficial layers of the water are led by the wings of the trap to the net at the apical end. Catch of fry may be expected whilst the incoming current lasts. Sometimes these fry traps are so modified when set that they are self-adjusting with the rise and fall of the tide. As soon as the catching net begins to accumulate fry, bowls, cups or small basins are used to scoop and transfer them to bigger, white-enamelled basins. Here the dirt and debris are removed and the undesirable species are sorted out. The catch is accumulated and placed in earthern jars.

The fry shore seine or " salap " is simply a rectangular net made of fine-meshed abaca fibre cloth

(*sinamay*) so constructed that it forms a shallow bag at its central portion. This device may vary from 1 to 5 metres long by about 1 metre wide. Its margins are usually lined with a coarse cotton twine or abaca fibre rope. For convenience in the operation, two poles may be fastened at both ends of the shorter sides. This net is operated by merely dragging it along flat, sandy shores during the fry season. The narrow salap may be operated by one man, while the wider ones require two persons. During catching, the net is periodically raised and the fry are accumulated at the centre of the net by rolling the pole handles towards the centre and at the same time maintaining the bag partially immersed in water. The fry caught are scooped with bowls or cups and placed in earthernware containers.

The dip net known as "panagap" or "salok' and the scissor net or "sakag" are of fine meshed and mounted on a triangular frame. The dip net is a smaller affair. It is provided with a handle at one point and its sides vary from ½ to 1 metre in length. It is handy and can be operated by one man to scoop the fry, especially in narrow tidal streams. Because its operation covers only a limited area, this method is practical only during the height of the bangos fry season.

The scissor net is also operated by one man along sandy shores. It is so-called because the frames of bamboo poles are only provided at two sides of the triangle and these frames are bolted at the angle point where they meet, such that the angle formed can be freely increased or decreased during operation. One side is unframed but provided with a lining of abaca fibre rope or coarse cotton twine. This gear is operated by one man by pushing from the end where the frames join. This is practical in level ground along sandy shores.

Sorting the catch.—There are several methods by which the desirable species of fish fry are selected and the undesirable ones eliminated. The surest and most reliable so far is the careful hand-sorting method. Experienced bangos fry-catchers can easily recognise the bangos fry. The fry of other species are picked out with fine-meshed scoop nets or with porcelain or enamel cups or bowls or even large valves of clams or mussels.

Some fry-catchers make use of a sorting chamber. This is of cylindrical shape, made of fine wire screen wound around a wooden or bamboo frame. The bottom end may be closed by either an abaca fibre cloth or a fitting piece of board. The mesh of the screen which is about 2 millimetres allows the slender bangos fry to pass through but excludes most of the other fry. The unsorted fry are all poured into the sorting chamber which is placed in a large basin that has previously been partially filled with water. The bangos fry swim out while the other fry remain in the chamber. These other species are then eliminated.

Counting and storage of the fry

After the preliminary sorting of the fry in the fishing grounds, some of them are counted and placed in earthen jars. Assessment of the catch is done by counting out the contents of this jar. Using this jar as a basis of estimate, the other jars are filled with approximately the same number of fry.

The jars are made of pottery clay. They are unglazed porous jars which are widely used in the industry. For bangos fry, jars capable of holding 15 to 20 litres of water are selected. During the catching season a great number of these jars are brought to the fishing grounds. Each jar is provided with a basal ring (dikin) of bamboo splits to make its base stable. This ring is firmly tied to the jar with bamboo or rattan splits and provided with two loops for use in lifting the jars. Once these jars are filled with fry and the proper amount of water, they are covered with banana or palm tree stalks and are usually gathered and stored under a shelter especially built for them. It is believed that if the fry are allowed to adapt themselves to the jars for a period of at least two days, they will be more resistant to the handling they will undergo later in transit. As a rule, preliminary storing and "acclimatization" accommodate from 1000 to 2000 fry in each jar. In transit each jar is filled with 2000 to 4000 fry.

Collection of the fry of jumbo tiger-shrimp

The tiger-shrimp, *Penaeus monodon* Fabricius is the species of penaeid that yields to cultivation in ponds for profit. The different methods used for catching milkfish fry are also employed in catching the fry of this species which usually appear in abundance after the milkfish fry period (onset of the rainy season).

An effective method used for the capture of tiger-shrimp is the fry lure or "bon-bon". This consists of small bundles of certain semi-aquatic grasses which are tied at regular intervals of about a metre on a long line of string, rope or split rattan or any available tying material. This is set near the bank of a tidal stream by securing the stretched line to bamboo or wooden poles so that the patches of lure float freely along this line. This method takes advantage of the habit of the shrimp to cling to water grasses and other vegetation. The lures are visited from time to time usually twice or thrice a day, and the catch is placed in earthenware containers by means of dip nets made of fine-meshed abaca cloth,

Collecting other species

In subsistence fishing operations along estuarine areas several types of gear are used, and because of their construction and the method of operating them, they incidentally catch juvenile fish which may be reared in the fish-ponds.

One of these methods is the crab trap or " bintol " which consists of a square net varying from 30 to 100 centimetres on each side. It is mounted on two bamboo split frames that cross each other. The trap is baited with meat or fish and set in tidal streams or shallow shores to catch crabs. Its meshes are often fine enough to trap also the small-sized crabs. These undersized crabs may be placed in live boxes for stocking in ponds. The blue crab and the swamp crab may also be collected with this gear.

The " salambao " is a giant dip net. This is operated on a huge raft of bamboos. The net is rectangular to almost square with sides of about 10 to 20 metres. It is lowered and raised in tidal flats and estuaries by a wooden post operated from the raft. It is used to catch shrimps, crabs and any fish that may come across its path. It catches also small mullets, and sometimes young " kitang " and " samaral " which are all good pond fishes.

The " palapad " or tidal fish trap consists of bamboo screens that are set along the shore during the high tide so as to enclose fish lurking along the banks of tidal estuaries. As the tide recedes, all fish, crabs, shrimps, mullets and the spade-fish within the trap are also caught. These may be collected for rearing in ponds.

Subsistence fishermen often use hook-pole-line fishing (binguit) on small wooden dugouts. This method often catches young sea bass and several species of snappers and groupers. Although these species are harmful to the bangos because of their carnivorous habit, they are raised in special compartments in the pond system. Their culture may be developed because of their high market value and the great demand for them.

Collection of marine and estuarine spawn in other Indo-Pacific countries

The estuarine areas of fish-ponds in Java are stocked with *Chanos chanos*, for which the fry are collected on the sea-coast, as in the case of the Philippine industry. The fry collecting areas are in the neighbourhood of the Spermonde Islands, southwest of Celebes, Madura and its neighbouring small islands, and the north coast of Java. The capture methods are described by Schuster (1949).

The success of mixed species pond-culture with the grey mullet as one of the components is a recent development in China which led to the demand for the grey mullet fry. Lin (1940) described two methods of catching the mullet fry.

According to Dr. Robert W. Hiatt, the method of collection of mullet and milkfish fry in Hawaii is to observe small fry, approximately one inch in length in large schools near the shore of sandy-bottom reef flats. The fry are surrounded by fine-meshed nets and are scooped up into buckets and carried to the ponds where they are dumped in. The mullet and milkfish fry are handled in the same manner and they are the only species of fry captured for pond-culture. He is of the opinion that the pond industry in Hawaii is comparatively unimportant and is leading towards a decline.

Milkfish is also widely cultivated in Taiwan but so far no reliable information could be gathered as to the methods of collecting fish fry in this region.

Mention is made here of the successful cultivation of the Japanese eel, *Anguilla japonica* (Schlegeal), in Japan. The adults of this species spawn in the open sea in the Mid-Pacific Ocean, and the leptocephalus larvae make a very long landward migration toward the Asiatic sea coast. After about two years, they reach the coast of Japan and at this time they are in transparent, glass-eel form called elvers. They are caught in large quantities when they begin to ascend the rivers and subsequently stocked in ponds for rearing.

PROBLEMS AND RECOMMENDATIONS ON FRY COLLECTION

Based mainly on investigations on bangos fry catching in the Philippines, the collection of fish spawn may be divided into six major considerations :

1. Organization and coordination of the industry.
2. Improvement of fishing gear used.
3. Conservation of the species of economic fish spawn.
4. Storage and handling during and after collection.
5. Methods of determining the desired species and practical means for their quick separation and isolation.
6. Survey of new sources and fishing grounds to meet future needs and possible expansion.

Organization and co-ordination of the industry

The collection of fry for the fish-pond industry has become a specialised phase of this fishery. As a matter of fact, it is an industry in itself. The main

responsibility of providing fry usually involves the established practice of leasing the fry grounds to regional and local concessioners. These concessioners employ local catchers consisting of whatever man-power is available, including women and children of families residing in coastal villages. They are widely scattered in their particular localities. There is no organization or co-ordination of their efforts and activities. Very limited capital is invested in the industry. This gives anomalous profits to unscrupulous middlemen to the disadvantage of the catchers and the pond-owners. Lack of organization and co-ordination has retarted the improvement of techniques in catching, storage and handling. Sometimes, the fry from the rich collecting grounds do not reach the extensive fish-ponds where they are needed most. Consequently, a great portion is wasted due to defective distribution. The formation of a national organization to handle and co-ordinate the industry may help to effect desired improvements.

Improvement of gear used

The survey of the methods of collecting fish fry now in practice shows that these are very slow and limited in scope besides employing a comparatively large number of personnel. The influx of catchers to the fishing grounds is great during fry season as long as high prices and great demand are maintained. This practically stops when fry get scarce making the small catch unprofitable, and also when there are great numbers of fry, resulting in very low price or no demand for them.

Improvement in gear should be aimed at mechanization in order to eliminate the large personnel needed to be employed and to cover a larger ground and thus make catching during scarce periods still profitable. A projected experimental test of a bangos fry trawl designed by Porfirio R. Manacop and Boris O. Knake is being planned during the fry season in 1951. This is based on the assumption that the fry as in the case of bangos are laid in the open sea where fry may be scattered along the shoreline even on steep or rocky banks where the catchers ordinarily could not operate. Catching may possibly be tried also a little away from the shore.

Conservation of economic species of fish spawn

It has been noted that many fry of various species are wasted during the collecting operation. This wastage is due in part to faulty handling, overstocking of containers, and inadequate sorting. An especially unfortunate practice is the discarding of unwanted species, the fry of which are thrown on the beach to die. No effort is made to salvage them. This practice needs regulation. The catchers should be compelled by law and aided by proper education to conserve the fry of these other fish in order to contribute towards the conservation of other economic sea fisheries. Salvage of the fry of undesirable species should be initiated for transplantation purposes.

The existence of dynamite fishing which is frequently observed within or near the fry grounds may have a telling effect to the future supply. In this way the wholesale killing of the spawners as well as the fry and destruction of the natural spawning ground may result.

The natural entrances by which the fry have access to inland waters such as tidal streams, bayous and tributaries of river systems are fast being modified by natural forces including floods, current, waves and winds. Sometimes these changes make such areas unfit for the fry and fishing for them unfavourable. Man-made modifications of such areas by engineering works and industrial plants should also make provision for preserving the natural abode of economic fish fry. Pollution from population centers and industrial plant wastes are potent factors in reducing the supply of economic fish fry throughout the region and may result in a serious problem of depletion unless preventive steps are undertaken.

Storage and handling during and after collection

With the collection methods now in existence and the short duration of the fry " runs " the accumulation of a sufficient amount of fry for distribution takes considerable time. Improved methods of storage and handling during this period must be devised. In order to reduce the mortality of the fry during temporary storage and in transit from the fishing grounds to the fish-ponds, efforts should be undertaken to determine the optimum required per container and the physical and chemical requirements of the water media of the fish fry. The use of porous, unglazed, earthen jars has proven to be quite successful. This porosity enhances evaporation, thereby providing a more or less constant and low temperature of the water. The problem with this container is the risk of breakage which often leads to great losses. A type of unbreakable receptacle which could maintain water at low temperature and provide ample aeration should be devised for improvement. The use of tin cans properly aerated by air compressors may be a good suggestion. Provision for maintaining the water in the receptacle at low temperature is needed. Such a container should also facilitate the frequent changing of water and removal of any dead fry. Fry shades are often maintained in the fry grounds to good advantage.

Methods of recognising desirable species and means for their easy and quick separation and isolation

The size of the live fry, its mortality and striking similarity, in form and behaviour, to other undesirable species presents another problem during collection. Some of these undesirable species often prove to be predators of the desired species when stocked in the ponds. In spite of the several ingenius methods used for isolation, still not a small amount of mortality is attributable to the presence of the undesirable species. The difficulty of separating the desirable species also increases frequency of handling the fry, which often leads to weakening and death of the fish.

Survey of new sources and fishing grounds to meet future needs and possible expansion

The fish-pond industry has proved to be a very lucrative one. Its expansion has been rapid. Yearly more and more fry are needed to stock new ponds which are being built in scattered localities in many countries in the region. More intensive collection from existing grounds and the survey of possible new sources are imperative. New sources near the newly-developed fish-pond areas are necessary for the success of the new projects.

In the case of milkfish for instance, the development and expansion of the tuna long line fishing will create a great demand for a large amount of milkfish fingerlings. This will entail more fry for more turnover of milkfish to be channelled as bait for tuna long lining.

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3

FISH SEED INDUSTRY IN INDIA

by

T. J. Job*

ABSTRACT

The salient features of the existing state of the fish seed industry, with special reference to food fishes, in different parts of India are described.

Details of the Bengal trade in spawn and fry of the major carps like *Catla*, Rohu, Mrigal and Calbasu is detailed. Seed collection and stocking of carps such as *Labeo fimbriatus* and the transplanted *Catla* in the southern region are also described. Reference is made to seed of salt-water fish like *Chanos*, Mullets, Pearlspot, etc. in Madras, of air-breathers and other predaceous food fish such as Murrels, *Anabas*, *Clarias*, *Heteropneustes*, etc., in various parts of the country, of exotic food fishes like Gourami and Mirror Carp, and of the important game fishes. Discussing the scope for improvement, the prospect of increasing seed sources, improving methods of collection, handling and transport, the organisation of fish marketing and distribution, creation of new markets and adjustment of the supply to the growing seed demand are explained.

The collecting of fish seed for stocking selected waters has been practised in India from very ancient days. A traditional trade in carp seed exists in Bengal where it has a place of importance in the seasonal activities of the market. The price of spawn in Calcutta in 1950 rose from about Rs. 100 to as much as Rs. 500 per kunka,** and with the reduction of spawn-collection grounds available to India after the partition, and with pisciculture rapidly extending in the various cultivable waters in the country, as also in other lands of the Indo-Pacific area, the industry has a bright prospect, provided it is promoted on rational lines. In this paper an attempt is made to present the salient features of the existing state of the industry with reference to the different kinds of fish seed in various parts of India, with certain suggestions for improvement. My thanks are due to the various State Fisheries Departments for the details furnished by them.

Though fish hatchlings and later stages might appropriately be termed "seedlings", in fish-farming practice the term "fish seed" generally signifies spawn, fry and fingerlings which are used for stocking waters. Strictly speaking, "spawn" means a mass of laid eggs with some hatchlings which may be associated with them, but in trade the term 'spawn' is loosely applied to cover eggs (*Dim*), early fry, i.e. sac-fry or yolked larvae (*Dimpona*) and older fry up to 1½" (*Dhanipona*). "*Phuldhani*" denotes fine dhanipona. Fingerlings(1½"—4") are called *Chara*. Young fish (4"-9") go by the name *Chala* and larger ones up to about a foot are known as *Nala* (Jones, 1950). Associated with the various forms of fish seed but distinct from these are "seed fish" which are mature adults specially maintained for seed production or stocking purposes. The fish seed industry relates primarily to the seed of food fishes, while to a limited extent the activities extend also to game fishes, aquarium fishes and larvicidal fishes.

SEED OF FOOD FISH

Freshwater

West Bengal

Nowhere in India is fish culture so popular as in Bengal. The low deltaic nature of the country with well-distributed water areas, the non-vegetarian habits of the bulk of the population and the local preference for inland fish have greatly contributed to this abiding interest. In his very useful Note on the Fish Fry Trade in Bengal, Rahman (1946) has described the activities of the undivided Bengal Fisheries Department with reference to the carp spawn trade, as also the mechanism of the latter, the spawn collection grounds and certain defects and difficulties of collection and transport. Briefly stated, the present position of the major carp seed industry in West Bengal is as follows :—

Of the food fishes cultured in West Bengal, the major carps, *Catla* (*C. catla*), Rohu (*Labeo rohita*), Mrigal (*Cirrhina mrigala*) and Calbasu (*Labeo calbasu*) stand foremost. These carps spawn usually during the rains from June to September, and as the spawn drifts down the rivers (mainly the Ganges and the Bhagirathi (vide Fig. 1), it is collected from suitable shallow areas near the bank where the current is not too strong. The chief spawn grounds of Serajgunge, Rajshahi, Sarda, Kusthia, etc. are, after the partition of the country, no longer easily accessible to Indian spawn collectors, who therefore mainly concentrate in Lalgola, Dhulian, Nimtita Katma and Krishnagar within West Bengal. Some spawn from the border waters and adjoining areas

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** A measure of about 21 ounces (600 c c). The price soared up to Rs. 700 per kunka in 1951.

also find their way to Calcutta, but this is restricted, especially in view of transport difficulties across the frontier. A limited quantity of spawn is also obtained from the bundh type of tanks occurring in the Midnapore and the Bankura districts. While spawn is thus available in West Bengal from June to September, fry and fingerlings reared out of the spawn in nurseries continue to be available for another quarter, i.e. October to December. Hence the carp seed industry is practically a half-year activity in this part of the country.

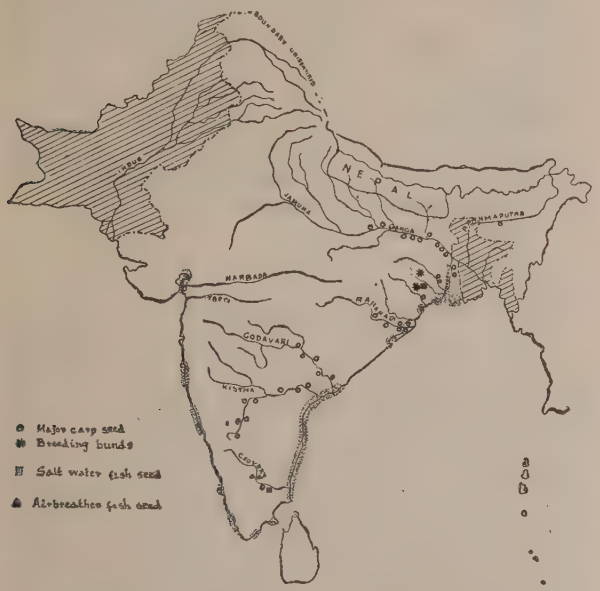

FIG. 1. Fish Seed Grounds in India.

The Indo-Pakistan boundary shown on this map has not yet been demarcated as an international boundary. The alignment, therefore, is to be regarded as approximate and is not authoritative.

In view of the unsteady availability of spawn, and because the major carps breed in bundh type of tanks while they do not usually breed in confined waters, the conditions conducive to the spawning of major carps have attracted considerable attention in India. The possible significance of various factors such as flood waters, rise of oxygen content, temperature, pH, molecular pressure of silt, shallow overflows, various meteorological factors, etc., has been suggested at a symposium on the subject (Hora, 1945). While some of these suggestions are backed by observational data, the factors which influence spawning have by no means been finally elucidated. When they are definitely determined, the essential conditions in the riverine breeding grounds and in the existing bundhs may be simulated in special carp breeding ponds which could be constructed for seed purposes. It is significant that the major carp, *Catla*, transplanted from Upper India to South Indian waters where the influence of both the monsoons is equally felt, breeds during both the monsoons. Further, the recent record (Alikunhi, 1951) of the spawn of *Labeo fimbriatus* (Bloch) and *Cirrhina reba* (Ham.) in shallow river beds during summer subsidence of water level opens up a line of investigation on the possibility of the regular major carps breeding even in the absence of flood water and thereby of extending the period of availability of carp seed.

Mode of collection.—A set of special spawn nets, four to eight or more in number, each being called a '*Benchijal*', is set up facing the current at a suitable part of the river, (vide Fig. 2). The *Benchijal* is

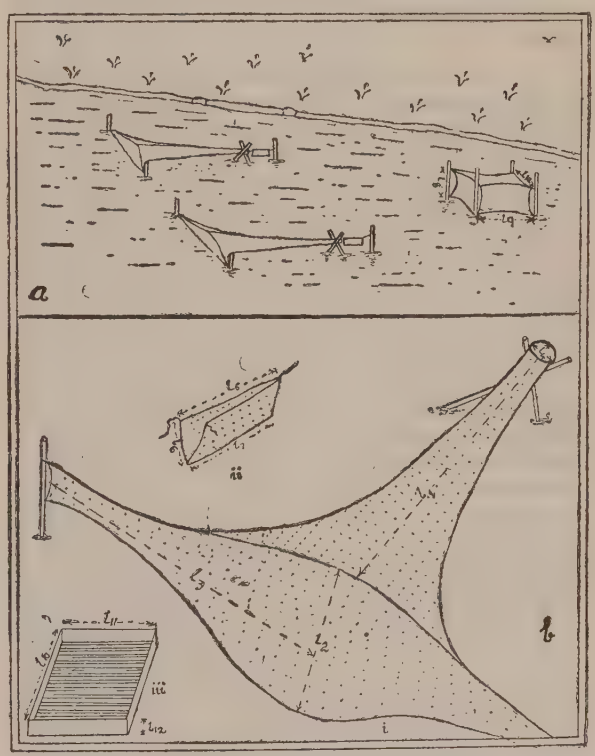

FIG. 2. Implements for collecting 'spawn'
(*a*) Two *benchijals* and a *hapa* in the river.
(*b*) Parts of a *benchijal* and a *chakuni*.
(i) *Benchijal* proper
(ii) *Gamcha*
(iii) *Chakuni*

small-meshed like mosquito netting and consists of a funnel-shaped net with two lateral wings to widen the receptive area of the mouth. It is fixed with the help of bamboo posts so that the net is kept stretched open with the mouth facing the current. The round opening at the narrow hind end is kept open by means of a circular ring of cane or split bamboo. To this end is fixed a second detachable small pocket-net called 'gamcha'. The gamcha is usually

shaped like a monk's hood, or it may be even like an open rectangular net, the hind end being slightly raised over the rest. The spawn caught within the wings and the mouth are led into the gamcha where they accumulate until they are gathered. The floating objects, debris, large-sized seed of catfish, etc., caught with the spawn, are removed by sifting through a rectangular sieve called "Chhakuni" and the spawn is transferred to a rectangular store-net called "hapa". The "Chhakuni" consists of a rectangular, wooden frame with a bottom screen of wire-mesh or bamboo grillage. The top edges of the spawn net, the gamcha and the hapa, when set, are kept raised a few inches above the water. The usual dimensions of the parts are indicated in the figure.

The spawn collected in the special nets belong mostly to *Catla*, Rohu, Mrigal and Calbasu in varying proportions. It is often mixed with considerable quantities of seed of the minor carps, *Cirrhina reba* and *Labeo bata* and of minnows and predaceous fish, such as catfishes and featherbacks. Spawn from "bundhs" (Hora, 1945 & Mookerjee, 1942), especially of the dry type, to which selected breeders are introduced, could be comparatively purer.

The spawn catchers.—The spawn collectors, who are fishermen, work in groups of about five to ten or more called *Savars*. Each Savar is under a leader who arranges the necessary investment and equipment and negotiates the business with spawn merchants in Calcutta. Three types of spawn catchers work in the Savars. (i) The "Malos" are professional fishermen who, after the seed season, spend the rest of the year fishing tanks and streams. (ii) The "Namasudras" are primarily agriculturists and resort to spawn collection during the season. (iii) Certain Muslims in petty business or cultivation also take to spawn catching as part-time occupation. A couple of months before the spawn season, each Savar leader gets an advance of about Rs. 500 to Rs. 750 from a spawn merchant on a simple receipt, agreeing to trade with him during the season. Each member of the Savar gets a share of the earnings, the leader receiving an extra share. The leader also receives a present of about Rs. 50 to Rs. 75 from the spawn merchant at the annual settlement of accounts. The Savar leaders take spawn grounds on lease from land owners called Mohalladars and Ijaradars who in their turn have taken lease of large tracts from the big landlords called Jamindars, who own the river banks. Some Mohalladars and Ijaradars operate the grounds also through their own Savars.

Disposal.—The spawn collected from the river is carried in earthenware hundies on slings and despatched by rail in special compartments to Calcutta. Colloidal earth is stirred into the hundy, and the hundies are shaken constantly, especially during stoppages. The water is also changed, at least partially, at intervals of about three to four hours en route. On receipt of the spawn, the Calcutta merchants keep it in wide-mouthed pots called "gamlas" and sell it to owners of ponds and nurseries. The water from the gamla is drained off and the spawn is strained in a piece of loose-woven cloth and the mass, which looks like soaked vermicelli, is measured out in "Bhaties". A Bhati is one-fourth of a Kunka and may hold from about 20,000 to 50,000 fish seed depending on the size of the latter. The price fluctuates between Rs. 50 and Rs. 500 per kunka. Since the spawn is to be sold at once and there are no arrangements for long storage of live spawn in the market, the prices vary greatly according to the quantity of daily arrivals.

Other States

The carp seed trade described above, especially from the riverine grounds, has extended on a small scale to the adjoining States of Orissa, Assam and Bihar. Seed collection and stocking on a limited scale have also been started in certain other States such as the U.P. and Bombay. In the past, the Madras Fisheries Department collected *Catla* fingerlings from the channels and paddy fields connected with the Godavery system and stocked them mainly in departmental waters. This activity has of late been extended to the collection of fry and fingerlings of this and other food fishes such as *Labeo fimbriatus*, *L. kontius*, *Cirrhina cirrhosa*, *Barbus carnaticus*, etc., from the riverine grounds. In connection with the Rural Fishery Demonstration work and the intensified fish production schemes of Madras, a great fillip has now been given to fish seed collection and stocking. While fry are collected with the help of nets modelled on the "*Benchijal*" of Bengal, the fingerlings are captured in dip nets and basket traps fixed in fields and channels. The young fish thus captured are conditioned for a day or two by starving them in a perforated enclosure such as a conditioning box with wire gauze sides kept in a tank, and transported in tin carriers by rail to the required Districts. While the villagers in the areas of fingerling collection have begun to gather them and stock their own ponds or offer them for sale, an organised seed trade like the one existing in Bengal has not yet developed in Madras.

The following statement of carp seed recorded to have been collected annually in certain other States would also indicate the general trend of increase in this line of activity.

No.	Name of State	Number of carp seed collected in recent years		
		1948	1949	1950
1.	Orissa	1,736,761	1,300,000	2,300,000
2.	U.P.	2,587,479	4,122,433	2,849,877
3.	Mysore	..	24,855	52,654
4.	Bombay	..	..	100,000
5.	Bihar (hundies of spawn)	1,051	730	1,650

Salt-water Fish Seed

Even with the fuller exploitation of the seed resources of fresh-water fish, there exists a need for increasing variety with bulk of the inland water crops. The seed sources of those euryhaline fishes which are easily acclimatised to fresh-water must therefore be exploited. Of these, the mullets, the *Chanos* and the pearlspot are the most important. Mullet culture on a limited scale is in vogue in Madras, Travancore-Cochin, Bombay and in the 'abad' (reclaimed) areas of the Sundarbans in Bengal. While in Madras fingerlings are departmentally collected from the estuaries and backwaters and transported to inland waters, in Travancore-Cochin, they are either led into embanked waters along with the tide or picked up from among fishermen's catches and stocked in farms ; excellent results have been obtained by such stocking in the brackish-water farm at Narakal. In Bombay and in the Sundarbans also the natural seed is led into enclosed waters along with the high tide. In the region of the Contai coast of the Midnapore District in Bengal, mullet fry are collected from the sea by the coastal folk and reared in their ponds. A small local trade in mullet seed occurs in the Diamond Harbour area of the 24-Parganas. Often the mullets are stocked along with carps in some of the inland waters and they yield a fairly good mixed crop.

Compared with the extensive *Chanos* culture prevalent in the Far East, the farming activity relating to this fish in India is extremely meagre at present, although fingerlings of this fish are collected from April to July from the coastal waters near Pamban, Tuticorin, Ennore, Muthupet, Chunnampet, Kundapoor, etc., and transplanted with success in certain confined fresh waters in different parts of the Madras State.

Since the pearlspot breeds even in confined fresh waters, the seed of this fish is comparatively easy to obtain. Systematic collection of the fingerlings of this fish from Adyar, Ennore, Sadras, Porto Novo, Kundapoor, etc. is a routine item of work carried out from September to March by the Madras Fisheries Department. The pearlspot transplanted to such interior States as Hyderabad has established itself there with ease. The sheltered backwaters along both the west and east coasts of peninsular India provide ample seed grounds of this fish. *Elops*, *Megalops* and *Lates* are other forms which are collected and stocked in greater or less numbers departmentally. The availability of saltwater fish and the scope for rearing them in freshwaters have been discussed in detail elsewhere (Ganapati *et al.* 1950; Job & Chacko, 1947).

SEED OF JOEL-MACH (LIVE FISH OR AIR BREATHERS)

In spite of their predaceous propensities, and of local prejudices against some of them, the common air breathers like the Murrels (*Ophicephalus*), the Climbing perch (*Anabas*), the Magur (*Clarias*) and the Singhi (*Heteropnuestes*) yield a valuable fishery in many wild waters and swamps as well as some cultivated waters. In Hyderabad, Mysore and parts of Travancore-Cochin and Madras, the Murrel is considered a prime fish and fetches comparatively higher prices. Indeed the economy of the culture of air breathers and allied predators needs due consideration. Results like those reported recently from some parts of India, as also from Thailand and Cambodia, lend support to the desirability of their culture in certain types of waters with inexpensive feeding arrangements.

In the irrigation wells in the Salem and Coimbatore Districts, Murrel fingerlings collected from the Cauvery and the Bhavani are stocked annually by the ryots ; but there is as yet no methodical trade in joel fish seed in those areas.

As for exotic food fishes, apart from the departmental collection and sale of the fingerlings of Gourami and Mirror Carp in Madras, the fisheries of these species have not yet attained such a magnitude as to permit private seed trade in them, although they hold some immediate possibilities particularly in the case of Gourami.

SPORT FISH

The Mahseer, which is the delight of the angler, is an inhabitant of the higher portions of the rivers. The recent discovery by a unit of the Central Inland Fisheries Research Station of the seed grounds of the Mahseer near Hirakud in the Mahanadi opens up the possibilities of seed collection and transplantation of this fish in suitable upland waters.

(*a*)

(*b*)

(*c*)

(*d*)

FIG. 3.

Collection and transport of fry and fingerlings

(*a*) Collecting fry with vertical screen net from boat in the Brahmaputra in Assam.
(*b*) Collecting fingerlings with hand dip nets in Madras.
(*c*) Transferring fingerlings from conditioning box to tin carriers in Madras.
(*d*) Transferring fingerlings from tin carrier to double tin in Madras.

The Murrel, which offers good sport, has already been referred to. A number of brackish-water fishes such as *Lates*, *Polynemus* and *Megalops* offer excellent sport and can be reared with ease in confined waters.

Of the exotic sport fish, the Rainbow Trout, *Salmo gairdnerii* (= *Salmo irideus*) in the Nilgiris and the Brown Trout, *Salmo fario* in Kashmir and the Punjab, are well known. The trout seed industry is fairly well systematised though restricted to the Game Fish Associations. Spawners are stripped and ova are artificially fertilised. The eggs are nursed carefully in hatcheries. The alevins and fingerlings are reared in nurseries, the latter being fed artificially.

PUBLIC HEALTH FISH

The Public Health Department as well as municipalities in Madras obtain supplies of small fish such as *Aplocheilus*, *Gambusia*, *Lebistes*, *Ambassis*, etc. which are of proved utility in the biological control of water-borne diseases such as Malaria and Guinea-worm. They are effective as well as inexpensive for application. With the extension of their use in the infested waters scattered about in the multitudinous villages where 95% of India's population reside, the scope of the public-health fish seed trade is bound to increase.

ORNAMENTAL FISH

The art of parlour aquarium keeping is still in its infancy in India, though there are numerous enthusiasts who are very earnest about it. Several gentlemen maintain excellent garden pools and fountain waters with a variety of ornamental fishes. At present there is only a small trade in aquarium fishes in Calcutta the species concerned being mostly the gold fish, *Carassius auratus*. Young of this fish are kept in small bowls with occasional change of water and sold in the New Market. There is in India a number of brilliantly-coloured, tropical aquarium fish such as *Colisa*, *Macropodus*, *Ambassis*, *Apolcheilus*, *Danio* and the small barbels, which afford good prospect for a lucrative trade.

In conjunction with the fish seed industry, there are also opportunities for organised trade in the seed of other items of fisheries such as prawns and oysters and sprouts and cuttings of edible and ornamental aquatic vegetables like water chestnut, water potato, water cress and water lilies. The provision of accessories and equipment such as fry nets, conditioning boxes, carrier cans, etc., related to the seed trade would also offer material for a subsidiary industry.

FISH SEED TRANSPORT

Earthenware hundies and double tins (Fig. 3) are the most common vessels for local transport of fish seed. Open tin carriers and sealed tins with oxygen are used for long distances including air transport. Large-scale cross-country despatches of major carp seed by air and rail from Barrackpore to Hyderabad, Nagpur, Bombay, Madras, Tripura and Bhopal have begun to be effected by the Central Inland Fisheries Research Station (Fig. 4).

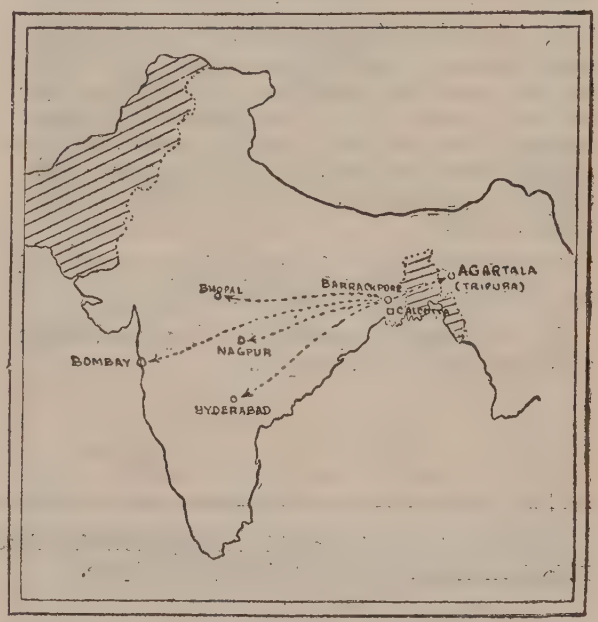

FIG. 4. Fish seed distribution to deficit States

The Indo-Pakistan boundary shown on this map has not yet been demarcated as an international boundary. The alignment, therefore, is to be regarded as approximate and is not authoritative.

DISCUSSION

A careful examination of the present condition of the fish seed industry in India reveals an urgent need for proper attention to the following:

Seed supplies have to be increased both in quantity and variety mainly with reference to the autochthonous species. Methodical survey and spotting of breeding grounds and natural nurseries in lotic and lentic waters is the primary step in this direction. Departmental activity has fortunately begun to be directed in this line. The determination of the conditions essential for the spawning of major carps and the provision of these conditions in "bundhs" for breeding them form another important measure, while in a few cases artificial fertilisation

and hatchery work would be of help. Due caution is required in introducing exotic species, and the possible reactions of the environment are to be ascertained before strange species are introduced into a new region.

2. Reformed technique of seed collection, handling and transport must be formulated. The Pond Culture Section of the Central Inland Fisheries Research Station has been able to elucidate certain causative factors of mortality and low rate of survival of carp seed during collection, transport and stocking and improve the yield by remedial measures.

3. The fish seed trade should be organised on an area basis so as to pool the seed resources and canalise the equitable distribution of the different species with reference to the requirements of the various regions. New markets should be created and the existing ones expanded by effective propaganda, and the supply should be adjusted to the growing seed demand.*

4. Nurseries must be properly prepared and maintained for the implantation of seed.

5. As a long range programme, improved strains of fish seed must be developed.

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*With a view to this, a Fish Seed Syndicate has since been organized under the auspices of the Central Inland Fisheries Research Station, Calcutta/Barrackpore.

4

PHYSIOLOGICAL REQUIREMENTS OF EGGS, LARVAE AND FRY DURING TRANSPORTATION*

by

S. P. Basu **

ABSTRACT

The effect of individual physico-chemical factors such as temperature pH, O_2, CO_2 etc. on the physiological requirements of larvae and fry of Indian Carps such as *Catla catla*, *Labeo rohita* and *Cirrhina mrigala* during transportation is investigated. Attempts are made to study the traditional practices employed by the fish farmers to check mortality during transportation and cultural operation. Scientific explanations for some of these practices are put forward.

A continuous flow apparatus in which the concentrations of the various factors can be adjusted to any desired level and the fish can be experimented upon for any length of time is described.

The results of over 200 experiments each extending for a period of 6-24 hours are reported.

Collection and transport of larvae and fry over long distances without mortality is an age-long problem which is important in any large-scale development of pond fisheries in the Indo-Pacific Region and particularly in India.

In Europe and several other parts of the world where the common European Carp, *Cyprinus carpio*, is cultured in ponds, there is no problem of collection and distribution of eggs and fry since this fish spawns in small confined bodies of water under suitable conditions. In India, on the other hand, the principal, cultured varieties of carps, such as *Catla catla* (Ham.), *Labeo rohita* (Ham.), *Cirrhina mrigala* (Ham.), *Labeo calbasu* (Ham.), etc., have not yet been induced to breed in confined waters, and therefore, their eggs, larvae and fry must be collected from the breeding centres in the rivers. Their subsequent transport all over the country presents many problems among which the considerable mortality risk is presumably paramount.

To ensure greater dependability of the supply of fish seed for cultural work, it is necessary to reduce the mortality risk. Although there are various indigenous practices intended to prevent mortality, it is evident that these are inadequate. It is, therefore, necessary to seek more effective methods and in order to do this it seemed necessary to establish a better knowledge of the physiological requirements of eggs, larvae and fry during transportation.

EXISTING METHODS OF TRANSPORT

Larvae (4-6 mm) and tiny fry (6-10 mm) of the principal culturable varieties of carps, such as *Catla catla*, *Labeo rohita*, *Labeo calbasu*, *Labeo bata* and *Cirrhina mrigala* are collected in rivers of Bengal by means of special, fine-meshed nets during monsoon months, *i.e.* May–August (Rahaman, 1946). Eggs are collected from the " bundhs " and hatched in " happa " in the course of 15-24 hours after fertilization (Mookherjee *et al.* 1944). The larvae and tiny fry collected are of a mixed variety, which often includes larvae and fry of predatory fishes also, but these are usually sorted out and thrown away. The larvae and fry are transported to Calcutta in open earthenware " hundies " of 6-10 gallons capacity containing 50,000 to 75,000 larvae of 4-6 mm in size for sale. The time taken for transport of larvae from the catching centre to Calcutta usually varies from 6-24 hours. On arrival at Calcutta, the owners of nursery ponds purchase this mixed variety of larvae. No attempt is made by the fish farmers to segregate the larvae into different species after collection as is done in China. The following indigenous practices are followed by the fish farmers in order to prevent mortality during transportation:– (1) the water of the container is changed occasionally during the period of transport; (2) use of earthen " hundies " in preference to other containers; (3) water is kept slightly agitated by means of hands during transport and (4) periodically some collodial earth is added to the water and the bottom of the containers is scraped out by means of a cloth rolled into a form of a rope, and the bottom mud is thrown out.

OBJECTS OF PRESENT INVESTIGATION

The objects of the present investigation are (1) to study some of the physical, chemical and biological changes during transport and their effects on the physiological requirements of larvae and fry during transportation ; (2) to assess the value of some of the traditional practices on scientific basis and (3) to evolve successful methods of transport on the scientific understanding of the physiological requirements

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of eggs, larvae and fry. Some of the physico-chemical factors studied in this connection are :—

(1) Temperature.
(2) O_2 and CO_2 tension.
(3) Hydrogen-ion concentration.
(4) Changes in the Biochemical Oxygen Demand (5-day 20°C B.O.D.).
(5) Bacterial population in the medium.
(6) The effect of concentration of larvae and fry in the medium and their survival rate.

MATERIAL AND METHOD

(a) Apparatus used for controlled experiment

More or less complicated apparatuses for the study of respiration in aquatic animals were constructed by Jolyet and Regnard (1877), Grehant (1886), Zuntz (1901) and Bounhiol (1905). Ege and Krogh (1914) have fully discussed the merits and demerits of the apparatuses, devised by previous workers, and developed a simple apparatuses the usefulness of

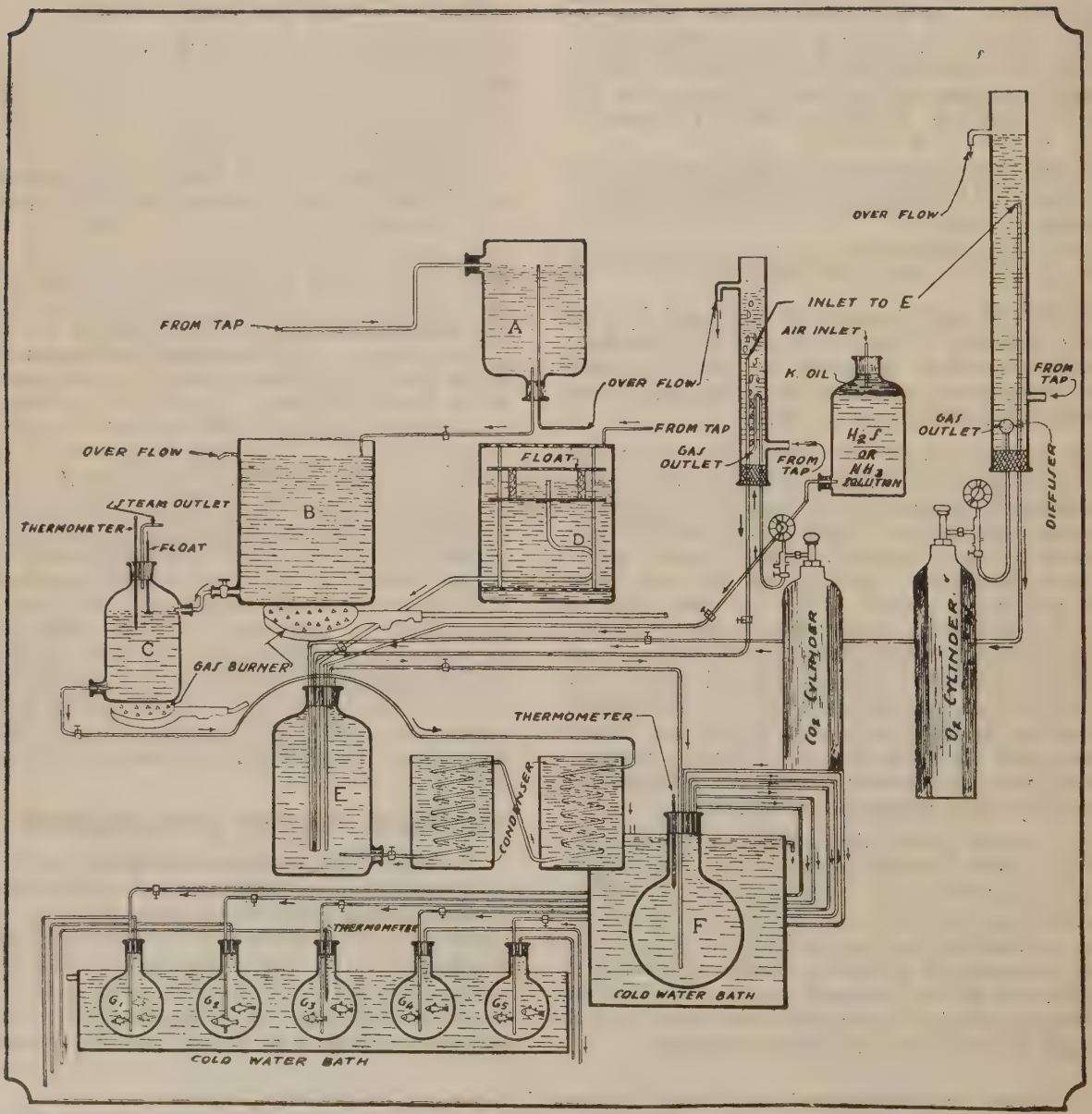


FIG. 1. Apparatus for Continuous Supply of Water containing varying concentrations of Oxygen, Carbon Dioxide, Sulphuretted Hydrogen and Ammonia.

which is limited, however, because experiments cannot be continued long enough and oxygen and carbon dioxide cannot be varied simultaneously in it. Shelford and Allee (1913) constructed an apparatus, but the technique for varying oxygen and carbon dioxide is very complicated. A special apparatus for continuous flow experiment has, therefore, been developed for this study. The apparatus (*Vide* fig. 1) is simple and can be easily operated. Any desired concentration of oxygen and carbon dioxide can be maintained and the fish can be exposed for any length of time.

Various methods, such as de-aeration, sealing the water surface after boiling with a layer of oil, and continued boiling of water have been tried as means of giving a continuous flow of de-oxygenated water. Finally, the author has standardised an apparatus which delivers per hour 16-20 gallons of de-oxygenated water with 0.05 p.p.m. or less of oxygen. Detailed description of the method for obtaining de-oxygenated water has already been described by the author (Basu, 1949).

Ordinary tap water is mixed in varying proportions with de-oxygenated water to obtain various concentrations of oxygen. This is drawn from a constant head reservoir which provides a uniform rate of supply of tap water during the period of experiment. For higher concentration (10, 15, 25 and 30 p.p.m.) oxygen is drawn from a cylinder and is bubbled through a diffuser in a column of flowing tap water maintained at a constant level. The O_2 charged water is drawn from the middle of the tube, so that the remaining half forms a balancing column and provides uniform concentration of O_2.

CO_2 concentration is controlled up to 100 p.p.m. by the use of a bubbling technique. CO_2 is bubbled at a constant pressure through a column of flowing tap water, the size of bubbles is controlled by passing the gas through a bent tube. The CO_2 charged water is drawn from the middle of the tube. For concentrations of CO_2 beyond 100 p.p.m. the gas is passed through a diffuser.

Hydrogen-ion concentration (pH) of the ordinary tap water is adjusted by buffer to different pH ranges. Experiments are carried out at a constant temperature inside an incubator, in which a flow of water of the desired pH is maintained.

Experiments on the effect of different temperatures are conducted partly inside an incubator and partly in cold room. For higher temperature of 36°C the incubator is used, for temperature range of 30°–33°C ordinary room temperature is used and for lower range 19°–22°C, cold room is used. Tap water is used to carry out all experiments in the continuous flow system apparatus.

(b) Fish used for experimentation

Larvae (4-5 days old and 4-6 mm in length) and fry (10-45 days old and 1.5-8 cm in length) of major Indian Carps such as *Catla catla*, *Labeo rohita*, and *Cirrhina mrigala* were used for these experiments. In the case of larvae, 500-1000 larvae weighing 0.5 to 1 gm each were used in each experiment whereas in the case of fry, the number varied from 5-30 according to size and the weight from 15-50 gms.

Fish were conditioned in the laboratory aquaria at least two days before being introduced to experimental flasks. Oxygen, temperature and other factors of the conditioning aquaria were recorded regularly. Sickly or diseased fish were discarded. The harmful effects which might have come from undue deposition of excretory matter in experimental flasks were avoided by starving the fish for at least 24 hours prior to the experiment. Fish immediately after each experiment were discarded. The fish for experiments were taken from stock at random and no fish kept in captivity for more than 2 weeks was used for any experiment. Dissolved oxygen, temperature, etc. of the pond, from which the fish were caught and brought to the laboratory for conditioning, were also recorded from time to time.

(c) Chemical analysis

The standard procedure of the American Public Health Association (1946) was followed for all chemical analysis. pH of the water was determined by using a glass electrode. Dissolved oxygen was determined by Winkler's method using Sodium Azide modification. Samples of water for CO_2 estimation were collected in a Nessler's tube under oil and titrated with N/22 Na_2CO_3 using phenolphthalein as indicator. The titrated value was checked against the calculated value based on pH and carbonate equilibrium. Alkalinity has been expressed as total methyl orange alkalinity in p.p.m. $CaCO_3$ by estimation with N/50 H_2SO_4 using methyl orange as indicator. Electrical conductivity was measured in mega ohms (10^{-6} ohms) units by the use of dionic water tester.

(d) Bacteriological analysis

Bacterial numbers were estimated by nutrient broth media with glucose by the use of dilution method. Dilution up to 10^{-10} was used and the seeded tube incubated for 24 hours in 37°C incubator. Most probable numbers were computed using McCardy's tables.

So far, more than 200 experiments have been carried out with different concentrations of oxygen,

carbon dioxide, pH, etc., and temperatures. Most of the experiments have been repeated.

EXPERIMENTAL RESULTS

(a) Effect of temperature

The results presented in the following table indicate the oxygen consumption at 3 different ranges of temperatures in a continuous flow system.

TABLE 1

Effect of temperature on the survival and Oxygen consumption by larvae and fry of Indian Carps

Temp. in °C	Milligrams of oxygen consumed by 100 gms of fish per hour			
Range	Larvae (4-6 mm)	Fry (3.5-6.5 cm)		
		Catla catla	*Labeo rohita*	*Cirrhina mrigala*
19.3—22	44.76	19.89	20.75	14.64
30 —33	150.50	30.93	30.97	25.92
36	226.04	75.00	75.00	48.88

Duration of experiments—4-6 hours. Observations recorded every ½ hour. Each value represents the median value of 8-12 results. Other conditions :—Dissolved oxygen 6-8.16 p.p.m., CO_2 nil-5 p.p.m.; pH 7.2-8.7.

From the comparison of the oxygen consumption figures at different temperatures, it is seen that with rise of temperature, there is a considerable increase in oxygen consumption both by larvae and by different species of fry. The Q_{10} values calculated according to van Hoff's Arrhenius Law between temperature 19.3 to 33°C vary from 1.45 to 1.74 in the case of fry and 3.02 in the case of larvae. At higher ranges of temperature 30-36°C, the Q_{10} values are higher and somewhat inconsistent. Statistical analysis of the data, however, indicate that temperature effects are significantly different in fry of different species. However, further controlled experiments are necessary before the full significance of these variations in Q_{10} values can be understood. The results, however, show that the consumption of oxygen, per unit body weight, by larvae is greater than by fry and also suggest that if the temperature of the medium can be maintained round about 20°C, the oxygen consumption of the larvae and fry can be considerably reduced and fish can be transported for a longer period.

(b) Effect of Hydrogen-ion concentration (pH)

Experiments were carried out with tap water adjusted to various pH values by buffer in a continuous flow apparatus; temperature was kept constant at 36-37°C. The following table indicates the oxygen consumption at different pH by larvae and fry of Indian Carps.

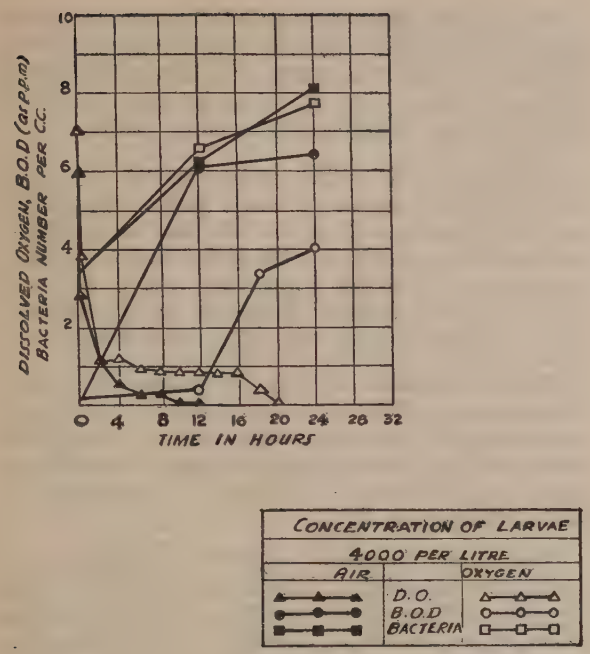
Comparing the oxygen figures in Table 2, it is seen that both larvae and fry consume maximum amount of oxygen between pH 6 and 7.9, and beyond these limits there is considerable decrease in oxygen consumption. Now, judging from oxygen consumption figures it is seen that the lower limit of pH tolerance is within the range of 4.25-6.0 whereas the higher limit lies somewhere between 7.9 and 9.4

TABLE 2

Effect of Hydrogen-ion concentration (pH) on the survival and oxygen consumption by larvae and fry of Indian Carps

Hydrogen-ion conc. (as pH)	Time in hours at which 50% larvae or fry are killed		Milligrams of oxygen consumed by 100 gms. of fish per hour	
Range	Larvae	Fry	Larvae	Fry
4.00—4.25	½	½	175.31	37.44
6.00—6.40	No mortality	No mortality	277.15	72.61
7.20—7.90	do	do	226.04	66.29
9.40—9.62	5½	do	149.64	47.99
10.00—10.95	½	1½	99.31	41.03

Duration of experiments—6-8 hours, excepting when the fish died earlier. Observations recorded—every ½ hr. Each value represents the median value of 12-16 results. Other conditions:—Temp. 36-37°C.; dissolve oxygen 6-7.2 p.p.m. ; CO_2—Nil. Fish used for each experiment—No. of Larvae 500—Size 4-6 mm ; No. of fry—3 of each variety (*Catla catla, Labeo rohita, Cirrhina mrigala*) put in the same flask, the size of fry being 3.5-6.5 cm.



GRAPH 1

Changes in Dissolved Oxygen, Biochemical Oxygen demand and bacterial population in the medium during transport of Larvae of Indian Carps.

D.O.—To be read as 1X
B.O.D. do. 20X
Bacteria—Unit corresponds to the power of 10.

in the case of larvae and between 9.62 and 10.00 in the case of fry.

(c) Effect of different concentrations of oxygen and carbon dioxide

The effects of different concentrations of oxygen and carbon dioxide in the medium were next investigated. The experiments were carried out in a continous flow system with various combinations of O_2 and CO_2. Firstly, various concentrations of O_2 in the absence of CO_2 were tested to determine the limits of O_2 tolerance. Secondly a number of levels of CO_2 such as 1, 3, 5, 10, 25, 50, 100, 150, 200, 250, 300 and 350 p.p.m. were tested at each level of O_2 to determine the lethal dose of CO_2 at various levels of O_2.

Experimental observations in regard to the effect of various concentrations of O_2 in the absence of CO_2 show that oxygen concentration below 0.5 p.p.m. is fatal to both larvae and fry, whereas they can live for 24 hours or more with 0.5–1 p.p.m. O_2. Higher concentrations of O_2 of the order of 10, 12, 23, 25 p.p.m. are not harmful to fry 4-8 cm in size. However, effects of higher concentrations of oxygen on larvae and fry below 4 cm are being investigated and the results will be presented elsewhere.

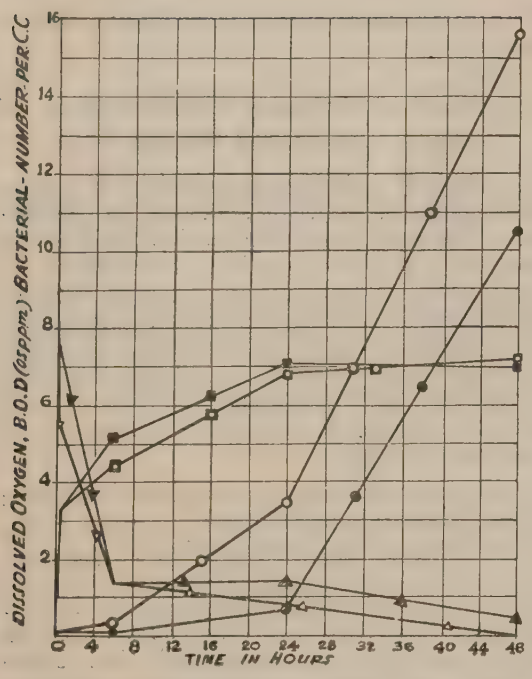
As regards the lethal limits of CO_2 at various concentrations of O_3, the results obtained are presented in Table 3.

TABLE 3

Lethal limits of Carbon dioxide at various levels of oxygen

Oxygen Conc. used as p.p.m. O_2	Larvae (4-6 mm)	p.p.m. CO_2 at which 50% or more fish are killed within 6 hours.					
		Fry (1.5-4 cm)			Fry (4 cm-8 cm)		
Range		Catla	Rohu	Mrigal	Catla	Rohu	Mrigal
0.5—1.0	2.5—5.0	10—15	10—15	10—15	95—100	95—100	95—100
1.0—1.5	4.0—6.0	175—180	175—180	175—180	300	300	300
2.0—3.5	100	225—250	225—250	225—250	300	300	300
3.5—4.5	..*	..	..	..	350	350	350
4.0—5.0	..	..	..	..	300	300	300
5.0—6.5	90—100	..	..	..	350	350	350
6.5—7.5	..	..	..	..	350	350	350
8.0—10.0	..	..	..	..	300	300	300
10.0—12.0	..	..	..	..	300	300	300
23.0—25.0	..	..	..	..	300	300	300

*The larvae and fry (1.5—4 cm) are available only for a limited period and hence the entire series could not be carried out in one season. Temperature for all experiments—27-29°C. Catla = *Catla catla* ; Rohu = *Labeo rohita* ; Mrigal = *Cirrhina mrigala*.


DISSOLVED OXYGEN, B.O.D (ppm) BACTERIAL NUMBER PER C.C
TIME IN HOURS
0 4 8 12 16 20 24 28 32 36 40 44 48
2 4 6 8 10 12 14 16
CONCENTRATION OF FRY
20 PER LITER
40 PER LITER
D.O
B.O.D
BACTERIA

GRAPH 2

Changes in dissolved Oxygen, Biochemical Oxygen Demand and bacterial population in the medium during transport of Fry of Indian Carps, with Oxygen in closed system.

D.O. to be read as 1X
B.O.D. ,, 20X
Bacteria—Unit corresponds to the power of 10.

The results show that at 0.5-1 p.p.m. O_2, 2.5-5 p.p.m. CO_2 is lethal to larvae, while at 2 p.p.m. O_2 and above, this lethal limit is increased to 100 p.p.m. Increases in O_2 concentrations above 2 p.p.m. do not affect the CO_2 lethal limits.

The lethal limit of CO_2 in the case of fry (1.5–4 cm) is 10-15 p.p.m. at 0.5–1 p.p.m. O_2; while at 1.0-1.5 p.p.m. O_2, this lethal limit is increased to 175-180 p.p.m. CO_2. The lethal limit is further increased to 225-250 p.p.m.CO_2, when O_2 is 2 p.p.m. or even above. Increases in O_2 above 2 p.p.m. do not increase the CO_2 lethal limit.

The lethal limits of CO_2 are found to increase when the size of the fry is increased to 4 cm–8 cm as compared with the earlier stages. The lethal limit of CO_2 is found to be 95-100 p.p.m. at 0.5–1 p.p.m. O_2, while at 1.0-1.5 p.p.m. O_2 and above, it is 300-350 p.p.m. CO_2.

The results therefore, suggest that during transport of larvae and fry, if the minimum oxygen level can possibly be maintained at 2 p.p.m.in the medium, there is less chance of mortality of larvae and fry within limits of 100 and 250 p.p.m. CO_2 respectively.

The amount of oxygen consumed by larvae and fry, at each level of O_2 in the absence of CO_2 and in the presence of various levels of CO_2 are being analysed and the results will be discussed elsewhere.

(d) Different conditions of transport

Effect of concentrations of larvae and fry in the medium.—The different conditions of transport and the effect of the concentrations of larvae and fry in the medium were investigated and the results of the experiments are presented in the following table.

TABLE 4

Effect of concentration of larvae and fry of Indian Carps on their survival under different conditions

Concentration of larvae and fry per litre.				Time in hours at which 50% larvae or fry are killed.	
Fish	Size	Number	Total/Wt. in gms	Open system	Closed system with O_2
Larvae	4-6 mm	1000	1.23	54	25
,,	,,	2000	2.46	6	20
,,	,,	4000	4.93	2½	16
Fry	2-4 cm	3	2.0	No mortality	143
,,	,,	7	3.9	100	71
,,	,,	16	6.7	72	54
,,	,,	25	11.7	8	47
,,	,,	50	23.0	4	27
,,	,,	75	34.5	3	14

The above results show a most striking feature that in the open system there is considerable drop in survival period when the concentrations for both larvae and fry are increased beyond a certain level. Thus in the open system 1000 larvae (1.23 gms) per litre will survive 54 hours, whilst 2000 (2.46 gms) per litre will survive only 6 hours, a reduction to one ninth, similarly 16 fry (6.7 gms) per litre will survive 72 hours, whilst 25 fry (11.7 gm) per litre will survive only 8 hours, again a drop to one-ninth.

Data on the oxygen consumption and CO_2 production both by larvae and fry in the open and in the closed system with oxygen were collected during the period of experimentation. Results show that in the open system CO_2 accumulation is less whereas in the closed system it is very high. Thus for 16 fry per litre, CO_2 tension never exceeds 40 p.p.m. at the end of 120 hours whereas in the case of closed system it goes as high as 220 p.p.m. at the end of 54 hours. This suggests that due consideration should be given to eliminate high CO_2 tension in the medium in the case of closed system. The full significance of the interactions of these factors which possibly contribute to the cause of mortality both in the open and in the closed system with oxygen can only be explained after a detailed statistical analysis of the data, which is in progress, and the results will be presented elsewhere.

In actual practice, the most important question is how many fish can be transported over a certain distance either in the open system or in the closed system. The choice between the system will depend on whether the requirement is for prolonged transport or economy, and whether the time lapse required for the journey falls within the critical limits of one or the other system. Thus, to put it very simply, if it is required to carry larvae for more than 25 hours and fry more than 48 hours, it is obvious that an open system with concentrations not more than 1000 larvae and 16 fry per litre must be used, whilst if the travel time is only 12 hours, a closed system with O_2 shall be preferred and the concentrations of larvae and fry can be 4000 and 75 per litre without risk. This only applies for one set of conditions as regards the vessel used, the amounts of oxygen and water, etc.

(e) Biochemical oxygen demand (B.O.D.) and bacterial population in the medium

The effects of faecal matter and the dead larvae and fry in the medium during transport were investigated. Graphs (1 and 2) show that oxygen is used not by the larvae and fry alone but also by faecal matter and that, with the death of larvae and fry, the bacterial population and the B.O.D.

TABLE 5

Effect of disinfecting agents in the medium on survival of larvae of Indian Carps (under closed system with O_2)

Treatment		Concentration of larvae per litre			Time in hrs. at which 50% larvae are killed
Disinfectant	Dose	Size in mm	Number	Total weight in gms	
Potassium Permanganate	1 p.p.m.	4.5-5	2000	2.06	3
	10 ,,	,,	1500	1.94	1
	20 ,,	,,	2500	2.63	Immediate O-hrs.
Chlorine	0.5 p.p.m.	4.5-5	1800	1.94	1
	1.0 ,,	,,	1900	2.19	Immediate O-hrs.
	2.0 ,,	,,	2100	2.32	,,
Electrolytic Silver	1 milli. amp. current	4.5-5	2000	2.19	3
	5 ,,	,,	2000	2.19	1
	10 ,,	,,	2000	2.03	Immediate O-hrs.
Silver sulphate	1 p.p.m.	4.5-5	1600	1.96	1
Sterilised water	..	4.5-5	2100	2.19	1
No disinfectant	..	4.5-5	2500	2.95	10

increase considerably and compete with the fish for the available O_2.

The results show that as the period of transport is increased, the demand for oxygen by the organic matter in the medium becomes significant.

(f) Effect of various disinfectants to control bacterial population and B.O.D. in the medium

Experiments were carried out with various disinfectants to control bacterial population and the B.O.D. in the medium. The results are presented in Table 5.

It is seen from the foregoing results that larvae lived for 10 hours without any disinfectant, whereas larvae are killed within a period of 3 hours even with small doses of disinfectants used. This suggets that disinfectants may be useful for controlling bacterial population in the medium but no material advantage can be gained by using the same as the larvae are affected by disinfectants even in small doses.

SCIENTIFIC BASIS OF THE TRADITIONAL PRACTICE

Experimental observations on the traditional practices employed by the fish farmers when transporting larvae and fry reveal that these are based on scientific principles. Thus:—

1. Occasional changing of water during transport reduces the chance of pollution.

2. Use of earthenware "hundies" in preference to other containers keeps the water cool by evaporation at the surface of the vessel.

3. Agitation of water helps to maintain O_2 and CO_2 at best level by increasing the air/water surface area for diffusion.

4. Addition of colloidal soil helps to separate the dead larvae from the living.

Experiments were conducted in adding soil to containers holding larvae. The results obtained from these experiments indicate that the colloidal clay separates the dead larvae (which otherwise float on the surface) from the living by carrying them to the bottom of the container where they become buried under the soil. The explanation of the phenomenon is thought to be that the dead larvae, infected with bacteria, usually carry a negative charge and the colloidal soil usually carries a positive charge. Since the larvae are small it is difficult to separate a mixture of dead and living ones and this soil process is therefore extremely useful. Moreover it is well known that the rate of decomposition of organic matter under sludge bottom is 1/100 times slower in comparison with that occurring in the body of the water and therefore this helps in maintaining favourable conditions.

Among other sanitary practices followed by the fish farmers to check mortality in fish ponds, mention may be made of the use of banana stem or juice, and keeping bags full of soap waste on the bank of the pond. Experiments have shown that addition of banana stem or juice acts as a buffer in the medium and helps to maintain optimum pH (Basu 1949-50). It is likely that constant leaching of soap waste from the bags kept on the bank of the pond helps to maintain the pH and reserve alkalinity of the pond.

SUMMARY

1. Oxygen consumption is found to increase considerably with the rise of temperature. The Q_{10} values between temperature 19.3-33°C for larvae is 3.02 whilst in the case of fry they vary between 1.45 and 1.74. At higher range of temperature 30-36°C, the Q_{10} values are higher and somewhat inconsistent.

2. Larvae consume 2-5 times more oxygen than fry per gram of body weight.

3. Larvae and fry can consume maximum amount of oxygen between pH 6.0 and 7.9.

4. Larvae and fry cannot tolerate oxygen concentration below 0.5 p.p.m. They can, however, live for 24 hours or more with 0.5–1 p.p.m. O_2. Fry (4-8cm) can stand higher concentrations of O_2 of the order of 10, 12, 23, 25 p.p.m. for 24 hours or more without any significant mortality.

5. Effect of CO_2 varies with O_2 concentrations in the medium. CO_2 is toxic at concentrations as low as 2.5–5 and 10–15 p.p.m. in the case of larvae and fry respectively when O_2 is maintained at 0.5–1 p.p.m. However, it is toxic at 100 p.p.m. and 250 p.p.m. respectively if O_2 is maintained at 2 p.p.m. and above.

6. Closed systems with O_2 above were found to be suitable for short period transport compared with ordinary methods. Transport over long periods under such conditions would be ineffective because of the accumulation of CO_2 in the medium.

7. Death of larvae and fry during transportation increases B.O.D. and bacterial load in the medium. These are significant at the later stage of the transport.

8. The use of disinfectants to control bacterial load in the medium proved impracticable because even small doses of disinfectants are lethal to larvae,

9. Experimental observations on the use of colloidal earth during transport of larvae by the fish farmers reveal that it helps in separating the dead from the living larvae. The scientific basis of other indigenous practices employed by the fish farmers, such as the use of banana stem or its juice and keeping bags full of soap wastes on the bank of the pond are reported.

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5

THE FITNESS OF ECOLOGICAL NICHES INTO WHICH FISH ARE INTRODUCED AT VARIOUS AGES AND THE SURVIVAL OF THE TRANSPLANTED FISH

by

Soong Min Kong*

ABSTRACT

A review is given of the data available on the limits of tolerance of fish of physical, chemical and biological factors, with special reference to the requirements of fish being transplanted in the Indo-Pacific Region.

When I was asked by the Executive Committee to undertake the preparation of a paper for the present symposium entitled " The Fitness of Ecological Niches into which Fish are introduced at various ages and the survival of the transplanted fish " I willingly agreed to do so. However, as the preparation of the paper progressed I realised that the title was too restrictive within the context of the symposium as a whole and demanded considerably specialised attention. So far as I am aware, little investigation has been made in tropical zones to provide adequate data for definite conclusions to be drawn on the relation between age and ecological environment in the transplantation of fish. Therefore, I have not restricted myself to this single problem in my paper, but dealt with it in general terms in the course of an analysis of transplantation of fish as a problem in relation to ecological niches.

In this paper, I have correlated field observations of my own over a number of years, and of other authors, in order to analyse the factors which control the life histories of individual fish and of fish populations in their natural environment and relate them to the practical problem of transplantation as an economic process. The paper is an interpretation in scientific terms of the natural history of the problem of transplantation of fish in relation to their environment. Literature and data are diffuse ; my own observations cover studies in the field in Malaya over the last fifteen years, of operations at a very simple level, but which have proved nevertheless successful. But, perhaps above all, this paper indicates the need for a great deal more physical, chemical and biological study if an accurate scientific interpretation of the field observations is to be achieved. This should not deter any worker from the practice of transplantation, but should he be able to carry it out together with a planned and detailed analysis of conditions, he will contribute to the scanty data now available.

The problem of the Fitness of Ecological Niches and its bearing on the survival of the transplanted fish is one of major interest to all fish culturists.

Whilst there have been, no doubt, instances of chance introduction proving successful, it is also true that in many cases, a lot of disappointment, time and expense might have been avoided if transplantations in general had been carried out in relation to the fitness of the environment for such transplanted fish.

Transplanted work may be divided into two categories :—

(*a*) Transplantation of species to stock rivers, lakes and swamps for natural growth.

(*b*) Transplantation of species for the stocking of ponds, for intensive culture.

It is clear, however, that whatever aspect is considered, the problem is basically the same, except that in the latter case, there is a measure of control over the environmental conditions.

For the successful transplantation of fish, then, an appraisal of the factors contributing to the ' fitness ' of the environment will need to be considered, and it is the purpose of this paper to attempt to assess the different levels of these environmental factors and their bearing upon the survival of the transplanted stock.

In this respect it may be advisable, at the outset, also to define what one would term *successful transplantation*, because conditions favourable for rapid growth of the transplanted fish may not necessarily be conditions favourable to its reproduction or vice versa. This is particularly so in pond-culture where conditions for rapid growth of the transplanted fish are maintained but where they often do not spawn or in some cases are harvested before they reach maturity. The same phenomenon may occur in nature. It has been noted that the introduction of the Brazilian cat-fish, *Pimelodus clarias* from rivers into impounded waters, produced rapid growth of the transplanted fish without development of gonads (Ellis 1936 and discussion). Similarly in heavily-manured fresh-water ponds in Malaya it has been

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observed that *Tilapia mossambica* showed rapid growth with absence of gonad development in the female fish (personal observation). The intestines of the fish were surrounded by a mass of fat. The reason for this, however, is still unknown, and it may well be that when too much fat is accumulated, gonad development is suppressed. For example, a fattening diet is said to reduce egg production in poultry.

For our purpose I shall define successful transplantation as one which fulfills one or both of the following conditions :—

(i) the fish are transplanted into new environmental conditions which favour their survival, and promote their growth and propagation.

(ii) the fish are transplanted into new environmental conditions which favour their survival, and promote their *rapid* growth, as for example, the transplantation of certain species of Chinese carp fry and *Chanos* fry into fattening ponds, where they have not been known to breed.

TRANSPLANTATION IN FRESH-WATER

The final environmental conditions which determine the survival and well-being of the transplanted fish are clearly the result of an inter-play of many factors. These may broadly be classified under the following headings :—

A. Physical Factors
B. Chemical Factors
C. Biological Factors

It must be remembered, however, that although the various factors may thus be delineated, they are themselves in dynamic equilibrium with one another, and that whilst the physical and chemical factors in themselves collectively determine whether a particular piece of water is favourable or unfavourable generally for fish and other aquatic organisms, the introduced fish themselves directly or indirectly through their own action on other forms of life exert a great influence on the environment.

For our purpose I shall, however, consider only those factors of which I think a fish culturist normally should take note before he undertakes transplantation work.

A. PHYSICAL FACTORS

(i) Temperature

The uniformly high temperature in tropical waters ranging from 25°C in lowland streams and rivers to 34°C in stagnant swamps does not, in general, impose an ecological barrier to transplantation as such, except to the introduction of salmonid fish like trout. On the other hand this uniformly high temperature fosters rapid growth of certain cold-water species introduced into this region.

The phenomenal rate of growth attained by species of Chinese carp imported as fry from China for stocking ponds throughout Thailand and Malaya is well-known and has been partly attributed to the warm climate in this part of the world (Birtwistle 1931). This general feature of uniformity of temperature in our waters extends even to our lakes where in most cases a true thermocline has not been shown to exist (Welch 1935).

Indirectly, however, the high temperatures influence the environment profoundly in relation to the dissolved oxygen content of the water, the rate of consumption of oxygen by fish and other organisms, and the rate of breakdown of organic substances and hence release of nutrients.

(ii) Turbidity

Turbidity of water is due to the presence of suspended matter. In tropical regions heavy rainfall and soil erosion are features contributing to turbid conditions in inland waters. This is especially so in stretches of rivers through cultivated lands. In certain cases, however, as in the Kinta Valley in Malaya, hydraulic mining has been the main cause of turbid conditions in the rivers. Turbidity conditions affect the environment mainly in two ways :—

(*a*) they reduce light penetration and hence slow down photosynthesis,

(*b*) they have a selective action on the fish fauna, by eliminating or keeping away fish unable to adapt themselves to the changed condition.

Whilst information on silt toleration and reaction of fishes is generally lacking, it is a remarkable fact that tropical fishes in general are able to tolerate wide ranges of turbidity. *Puntius schwanefeldii*, normally an inhabitant of clear waters is equally at home in waters ranging from that of clear mountain streams to one with a visibility of 4 cm in terms of the Secchi-disc (Birtwistle 1938).

I have myself obtained *Pangasius pangasius* in numbers by the use of tuba-root extract (Derris) from a river so heavily polluted by mining silt that visibility was only 2 cm–5 cm in terms of the Secchi-disc. Ecologically, however, there is evidence that extreme and prolonged turbid conditions tend to favour the development of a cat-fish type of fauna similar to *Pangasius*, *Wallagonia*, and *Clarias*,

with diminutive eyes and barbels to aid them in the search for food as they grub along the bottom. Hardenberg (1950) noted that under conditions of extreme muddiness in estuarine waters, a fish fauna with diminutive eyes and deep-sea affinity was developed.

(iii) Current

It is a well-known fact that current imposes a selective action on fish fauna. Certain fishes prefer swift waters of mountain streams—others live in swamps and backwaters.

B. CHEMICAL FACTORS

Natural waters contain a number of dissolved gases and solids and these are very important, because not only do they affect the well-being of the fish, but are themselves the basis of the food-supply for the fish.

(i) Dissolved Oxygen

With the exception of anaerobic bacteria and certain organisms ranging through the phyla Protozoa to Mollusca (Welch 1935) which are known to occur in the deep regions of lakes and which are able to survive for varying periods in the absence of oxygen in their environment, the vast majority of living organisms in water require oxygen for their metabolism. These requirements are derived from the dissolved oxygen in the water. Consequently the dissolved oxygen content of the water is an important index to its fitness for fish-life.

Oxygen requirements of fish.

A mass of literature has now been built up on the oxygen requirements of fish in general and it is well to see how they relate to conditions in nature. The following appear to be the salient features :—

(*a*) The consumption rate for oxygen by fish varies with the temperature of the environment. Ruttner (1926) has stated that for cold-blooded animals the rate of oxygen consumption and carbon dioxide output generally doubles with a temperature increase of 10°C.

(*b*) Certain fish have higher oxygen minimum toleration than others. Ellis (1937) discussed a mass of evidence from previous workers and arrived at the conclusion that " the upper limit of dissolved oxygen at which asphyxia may be expected in fishes, if there were no unusual complicating factors is, in general about 3 p.p.m. at 25°C." This is equivalent to 40% saturation. He further states that the dissolved oxygen which may be expected to maintain freshwater fish in good condition is in the region of 5 p.p.m. if the temperature is 20°C. or above. For a range of 20°C.–30°C. this will therefore mean an oxygen saturation of 60% to 70%.

(*c*) Excess oxygen leading to supersaturation of the water with dissolved oxygen as usually happens in ponds with abundant phytoplankton, has no ill effects on fish. This saturation may be 150-200%. Further, prolonged exposure of fish to high concentrations of oxygen of up to 300% saturation has been shown to have no ill effects on various species of fish (Wiebe and McGovock 1932). This characteristic of fish in general has been successfully applied in the aerial transport of fish under an atmosphere of oxygen (Le Mare 1949).

However, when one comes to analyse the above findings against the available limnological data covering our inland waters, one is forcibly struck by the general absence of such data. Surveys of inland waters might have been made by individual Fisheries Departments in this region in the past, but few of the data have been documented and made available. From whatever scanty information is available (Birtwistle 1938, Vaas 1947, Vaas and Schuurman 1949) it is clear that the dissolved oxygen content in most of our natural inland waters is well over 70% saturation, and therefore presents no hazard to fish. Only in cases where there is active organic pollution or active organic decomposition is it likely that the dissolved oxygen content drops to dangerously low levels. This condition of extreme oxygen shortage is, however, a frequent hazard in our swamps and has given rise to the evolution of a very successful group of air-breathing fishes with accessory air-breathing organs—the *Anabantids*, *Heteropneustids*, and the *Clarids*. Indeed in many of these fishes the evolution of their air-breathing organs has advanced so far and has become so important in their physiological make-up that many of them will die if prevented from coming to the surface for atmospheric oxygen (Das 1927).

Oxygen Depression in Ponds and sudden mortality of Fish.

Oxygen depletion in ponds with attendant mortality sometimes occurs in carp ponds in Malaya. It is noted that the grass carp *Ctenopharyngodon idellus* is particularly vulnerable and deaths usually follow dull days. The first symptom is when the

fish remain swimming near the surface, and as this generally happens long before dawn, it is often not noticed until the fish begin to die. Chinese fish culturists attribute this to ' over-richness ' of the pond-water and the remedy appears to be to let in fresh water.

Many examples of this phenomenon of sudden mortality both in ponds and in natural waters have been recorded (Sewell 1927, Pruthi 1932) and has been attributed to the lowering of the dissolved oxygen to the critical point which usually takes place in the early morning (Hogan 1933). Nocturnal depressions in the dissolved oxygen content in inland waters is a common occurrence and has been recorded for fish ponds (Wiebe 1934). More recently, however, the view (Powers 1937) has been advanced that the sudden mortality of fishes is brought about not by asphyxiation but by a physiological derangement brought about by alternate compensation of the blood of the fish to higher and then to lower carbon dioxide tension of the water. Powers' view is that fish come up to the surface to feed in the morning, and in so doing pass through a zone of high carbon dioxide tension near the bottom and then to one of lower tension at the surface.

(ii) Hydrogen-ion Concentration

An important means of understanding the conditions prevailing in natural waters is through the measurement of hydrogen-ion concentration. Since water derives its dissolved substances from the soil, substances contributing to the pH of the soil will themselves influence the pH of waters. Wherry (1920) lists a number of these substances.

In the tropics heavy rainfall and consequent leaching leads to the formation of soils poor in calcium and rich in iron oxide and alumina. It is therefore not surprising that Malayan soils often show pH range of 4.7 to 5.5. Certain coastal soils are even more acid (Belgrave 1928) and these have been shown to develop high acidity from the oxidation of sulphur compounds in decaying plant material of the soil (Wilshaw 1940). Hence most of the inland waters in Malaya are acid in reaction with a pH of 6.2 to 6.7. Peaty areas especially swamps may have a pH as low as 3.6.

Hydrogen-ion concentration as an ecological factor in inland waters.

It has been stated that the significance of pH as a factor of ecological significance has been overemphasized. Much experimental evidence has been accumulated to show that fish are able to tolerate wide ranges of hydrogen-ion concentration. Brook trout are said to have a facultative range of pH 4.6 to 9.5. Brown and Jewell (1926) found catfish and perch living in apparently good condition in a bog of pH 4.4 to 6.4 and also in nearby water of pH 8.2 to 8.7. Swamp-fishes such as *Trichogaster pectoralis*, *T. trichoperus*, *Clarias batrachas* and *Ophicephalus striatus* are able to tolerate waters ranging in pH of 4.0 to 9.0 (personal observation).

Schaeperclaus (1933), however, states that fish in heath and moor regions, which are consequently deficient in lime, suffer from acid mortality when the pH goes down to 5.5. Similarly Smeldley (1930) reported deaths of the Chinese carp, *Aristichthys nobilis* in ponds situated in acid soil in Singapore, on the advent of heavy rains. I have myself observed deaths of all species of Chinese carp including the hardy *Cyprinus carpio* and *Osphronemus goramy* under similar conditions in ponds in the same area when the pH dropped from 7.2 to 4.6 after continuous heavy rains lasting for two days. In the case of the *O. goramy* it was noticed that the hyaline layer over the eyes first became opaque and there were general signs of coagulation of mucus over the body. Rushton (1936) mentioned similar coagulation of mucus in trout fry exposed to acid water. Ellis (1937) as a result of extensive experiments states that a persistent pH of 4.0 or less is lethal to fresh-water fishes.

On the above evidence then, a pH of 5.0 would appear to be the lower limit critical for the survival of most freshwater fishes and that the upper limit would be a pH of 9.5. Therefore under natural conditions in view of this wide range of pH toleration of most fishes, hydrogen-ion concentration is not an important ecological factor.

There is, however, an important aspect which I wish to stress, and that is, hydrogen-ion concentration is a good, rough index to the degree of fertility and hence potential productivity of the water. A slightly alkaline reaction of the water is a very necessary aid to the breakdown of organic matter into simple substances particularly ammonia and nitrates. Indeed it has often been categorically stated that alkaline, natural waters are more productive than acid, natural waters.

Optimum pH

Various authors have stated that the optimum pH of the water for freshwater fishes is 7.0–8.0 (Schaeperclaus 1933 and others). Personal observations of Chinese carp ponds in Malaya also tend to show that this is the usual range in more productive ponds, the lower values being recorded in the morning and the higher values in the afternoon as a result of photosynthesis. The pH of waters is usually maintained by bicarbonate of alkaline metals, of which the most important is bicarbonate of calcium.

The dissolved bicarbonates form a "buffer" against violent changes in pH and are a measure of what is called the *Alkaline Reserve* of the water. The determination of this *Alkaline Reserve* is now considered of fundamental importance as an indication of the suitable potentiality of the water for fish (Schaeperclaus 1933). It is determined by titrating 100 cc of the sample water with N/10 HCl using methyl orange as indicator. On the basis of the number of cubic centimeters of Hydrochloric Acid required to bring about a colour change in the indicator, waters are classified as follows : Hey (1941), Huet (1947) :—

(i) 0–0.15 cc—too acid for fish culture,
(ii) 0.15–2.0 cc—usable,
(iii) 3.5 cc—optimum,
(iv) 7.0 cc and above—too hard ; tendency to deposit alkaline salts.

Another possible effect of low pH which might be mentioned is its effect on the physiology of reproduction. Hey (1940) states that trout had failed to reproduce in the Steenbras Reservoir in South Africa, the pH of which drops sometimes to as low as 4.2, due possibly to the lethal action of acid water on the milt.

(iii) Free Carbon Dioxide

Free carbon dioxide is generally present in water as a result of organic decomposition and the respiration of aquatic organisms. Its relationship with the oxygen content and the pH of the water is too well-known to need reiteration. In running waters as a result of mechanical agitation, the amount may be negligible. Similarly in highly productive waters, the concentration of free carbon dioxide may be used up during the day as a result of photosynthesis, and so only appears at night.

Physiological Effect of Carbon Dioxide.

The direct effect of high concentration of dissolved carbon dioxide on fish has received much study. Welch (1935) records that several authors have claimed that fish avoid waters with a concentration of 5 cc/litre of carbon dioxide. This is equivalent to 10 p.p.m.. Ellis (1937) found that streams with good fish fauna consistently carried less than 5 cc/litre of carbon dioxide.

Abnormally high concentrations of carbon dioxide of up to 200 p.p.m. are said to anaesthetise all species of salmon and steelhead trout (Fish, 1942). Surber (1933) showed that concentration of carbon dioxide of between 55 and 78 p.p.m. increased the post-eyed losses and the number of deformed fish in trout.

There are, however, few published data on the carbon dioxide content of tropical natural waters. Vass (1947) and Vaas and Schuurman (1949) listed some observations, and it would appear that only in swamps is the carbon dioxide content likely to rise to dangerous levels for fish.

(iv) Ammoniacal Nitrogen

The determination of the ammoniacal nitrogen content of natural waters gives a good indication of the extent of likely organic pollution. Natural, unpolluted waters generally do not contain more than 0–0.5 p.p.m. of ammoniacal nitrogen.

Ellis (1937) states that good fish fauna show a preference for waters containing less than 2 p.p.m. dissolved ammonia, and that the toxic effects of ammonium compounds is greatest in the pH range of 7.4–8.5. These conditions are, however, seldom met except in extreme cases of pollution. In carp and *Tilapia* ponds in Malaya, heavily manured with pig dung, concentrations of up to 4 p.p.m. of ammoniacal nitrogen at pH 7.3–7.5 have been observed to have no ill effect on the fish.

(v) Dissolved Solids

The food supply of fish in natural waters is based on the food-chain which has its genesis in the nutrient salts dissolved in the water. The most important of these are compounds of calcium, potassium, phosphorus and nitrogen and their significance in the economy of pond-culture has been discussed (Neess, 1946 and Le Mare, 1950). Since these dissolved substances are mainly derived from the soil, the chemical composition of the underlying and surrounding soil should be an important factor for consideration in transplantation of fish.

C. BIOLOGICAL FACTORS

(i) Suitability of Transplanted Fish

Fish differ in their toleration to various physical and chemical factors. The swamp-fish, of the genera *Ophicephalus, Clarias,* and *Trichogaster* are able to withstand high temperatures, low pH and low dissolved oxygen content better than most riverine fish. The common carp *C. carpio* is so hardy that its distribution is world-wide. Similarly fish of the cat-fish type are more adapted to extreme turbid conditions. The choice of a suitable fish should therefore be related to the physical and chemical conditions of the water ; in addition, its inter-relationship with other fish, either as prey or as predator, should also be considered.

(ii) Relation of Age, Size, and Density of Population of Transplanted Fish to Survival

In stocking both ponds and open waters the basic principle for obtaining maximum survival rate is, of course, to introduce fish of size as large as possible in order that they may hold their own against predators. The survival of the introduced fish is conditioned not only by such enemies as birds, otters, snakes, etc., but also by the presence and relative density of other fish in the population of the new environment either as predator, or as competitor for the same food. Much has been published on the relation of age, size, and density at stocking to survival rate in open waters and in ponds with regard to such fish as bass, trout, and salmon in temperate countries. In our region, however, little seems to have been accomplished in this direction.

Even in pond culture of some of our most common species, little as yet has been done to establish a relationship. Schuster (1949) states that mortality rate of *Chanos* from fry stage to marketable size may be 80%, but a yield of 30–40% is not unusual. Birtwistle (1931) records that stocking with 6″–7″ Chinese carp results in a mortality not exceeding 30%. Chinese fish-culturists in Malaya generally reckon on the basis of 70% loss in stocking with 2″–3″ and 30% loss with 6″ fry in their culture operations with Chinese carp comprising an assortment of the three species *Ctenopharyngodon idellus*, *Aristichthys nobilis*, and *Hypophthalmichthys molitrix*. These figures are obtainable only when care is taken to exclude such predators as *Ophicephalus spp.*, and *Clarias spp.* Of these *Ophicephalus spp.* are the most predaceous. The presence of any of these fish may well reduce the survival rate to only 10% when stocking with 2″–3″ fish.

(iii) Suitability of Spawning Conditions

The choice of the species of fish should also be related to suitable environmental conditions for its propagation.

In ponds, it has been found that whilst some species, as for example, the Chinese carp *Artistichthys nobilis* and *Ctenopharyngodon idellus*, do not spawn in captivity, others like *Osphronemus goramy*, and *Cyprinus carpio* will breed freely. Others again will only breed freely in captivity under certain conditions. The successful culture of *Osteochilus hasselti* in ponds in Indonesia may be attributed to the provision of special spawning ponds (Buschkiel 1929). In Malaya it has been the practice to rear this species together with *Osphronemus goramy*, *Puntius schwanefeldii* and *Helostoma temminckii* in the same pond, with the result that fry production of *Osteochilus hasselti* was negligible (Le Mare 1949). Similarly the Indian carp Rohu, *Catla* and Mrigal are said to require special spawning tanks (Hora 1945) and *Etroplus suratensis* will breed freely in ponds only when stones and tiles are placed in suitable positions.

(iv) Food Supply and Feeding Habits

The availability of food in quantity and suitability for the transplanted fish at any particular age is of prime importance and, as already mentioned, is closely related to the amount of nutrients in the water. Phenomenal results have often been obtained in stocking of virgin waters and ponds, owing to abundance of natural food. These are, however, seldom maintained and most waters show a decline in yield after a period of years (Ellis, 1936, and Le Mare, 1950).

The aim of all transplantation work should therefore be to introduce fish that will utilize available food supply. Hoeks (1941) records phenomenal increase in fish production in Tempé lake (South Celebes) following the introduction of two herbivores, *Trichogaster pectoralis* and *Puntius javanicus*, which were able to feed on the available algae food. Similarly, high yields of *Trichogaster pectoralis* were obtained following its introduction into paddy-fields in Krian, Malaya (Soong 1948).

Importance of availability of suitable food for young fish.

The most vulnerable period in the life of all fish is at the time when the yolk-sac is absorbed and they begin to feed. In this connection it is essential to remember that whilst fish may be classified according to their feeding habits broadly into herbivores, carnivores and omnivores, the young of all fish require an abundance of plankton. Indeed the success of many an aquarist in raising exotic fish may be attributed to his having solved the problem of finding plankton or a suitable substitute for his fish at this critical period. Langlois (1947) attributed major fluctuations in abundance of fish in Lake Erie to an environment which fluctuates in its suitability for larval fish, especially in availability of planktonic food at the critical periods rather than to depletion by overfishing. Therefore the primary consideration for the successful transplantation of fry will be the provision of ample planktonic food.

Ability of fish to adapt themselves to different foods.

The ability of fish within their broad classification to adapt themselves to different foods is an important consideration in all transplantation work. Schuster (1949) has brought out the remarkable fact that *Chanos chanos* shows anatomical adaptation when fed on different diets of blue-green and

green filamentous algae respectively. He also showed by chemical analyses, that blue-green algae were more nutritious than the green filamentous algae. These two findings, that fish will adapt themselves to available foods, and that the available foods may differ in nutritive value, are, I think, important considerations in the assessment of fitness of ecological niches. In short we should consider not only the types and the availability of food as usually estimated by the state of fullness in stomach content analysis, but also the question of the relative nutritive values of the types of foods that are eaten. There is the possibility that a fish may appear to have abundant food and yet is actually undernourished. One of the implications of this is discussed in the next section.

Relation of food to fecundity.

In relation to our study of the factors limiting the abundance of *Trichogaster pectoralis* in different parts of the Krian paddy-fields in Malaya, it was noticed that the fertile area in relation to rice production was an area near the sea-coast where the pH of the water was 7.0–7.5. Here the yield of *T. pectoralis* was also consistently high, of the order of 200–400 lbs. per acre per year, whilst in the inland acid area, where the pH was 6–6.8, the yield was only 10–50 lbs per acre annually. Examination of the fish from the two areas showed that the fish in both areas were apparently getting enough food as the stomachs were invariably found to be full. There were, however, differences in the types of food eaten and these differences were directly related to the available food supply. Fish from the alkaline area were feeding on zooplankton and blue-green algae, whilst those from the acid area fed on green algae (mostly desmids) and detritus. An examination of the ovaries of ripe female fish from the two areas over a period of seven months showed that the average weight of the ovary of a mature female from the alkaline area was 1.7 times that from the acid area. Hence it would appear that the quality and quantity of food in the fertile area has a direct bearing on the fecundity of the fish and helps to explain the remarkable difference in yields obtained with the same fish in the two ecologically different areas.

Tables I, II and III show the main physical and chemical features of the water and soil from these two areas.

TABLE I—TEMPERATURE AND DISSOLVED OXYGEN CONTENT OF WATER (1941)

Locality	Daily Temperature Range	Oxygen saturation % during "weeding" period. May-June	Oxygen saturation % during growing period of pady. July-December
Tanjong Piandang ..	27—31°C	—	55
Selinsing ..	28—33°C	8	50

TABLE II—WATER ANALYSIS—CHEMICAL

September 1941

Locality	Annual yield of T. pectoralis/acre	Results expressed as parts per million							
		Cao	P_2O_5	No3	Amm N2	Cl	So4	PH	Carbonate hardness in terms of $CaCo_3$
Tanjong Piandang	200—400 lbs	14.6	1.6	0.15	0.15	196.7	25	7.0	84
Selinsing ..	10—50 lbs.	4.8	0.01	0.04	0.30	3.6	20	5.9	15

TABLE III—SOIL ANALYSIS—CHEMICAL

Locality	Percentages based on Hydrochloric acid extracts						
	K_2O	P_2O_5	CaO	Sesqui-oxides	MgO	N	C
Tanjong Piandang (T) * ..	0.39	0.14	0.29	23.1	0.67	0.21	2.1
Do. (S) * ..	0.43	0.11	0.48	19.0	2.0	0.22	2.31
Selinsing (T) † ..	0.74	0.034	0.969	21.05	0.08	0.27	3.78
Do. (S) ‡ ..	0.70	0.039	0.043	14.11	0.049	0.14	2.37

The higher pH, calcium and phosphorus values of Tanjong Piandang water and soil as compared with those of Selinsing are worthy of note, in view of the importance attached to these elements in organic production.

Table II is of interest because it shows that the oxygen content of the water in these two areas tends to fall to zero at the time when the fields are cleared of swamp grasses and are being dug over. This period of oxygen shortage restricts the fish fauna to air-breathers, the most important of which are the introduced *Trichogaster pectoralis* and the indigenous fish *Clarias batrachus* and *Ophicephalus striatus.*

These three fish differ essentially in feeding habits. *T. pectoralis* is an algal feeder, *C. batrachus* a bottom feeder, feeding on worms, ostracods and the young of other fish and *O. striatus* is a carnivore, feeding on insect larvae, tadpoles, frogs and other fish. The three would therefore appear to fit into the ' principle of association of species ' so often stressed and advocated in pond-fish culture.

(v) FECUNDITY OF TRANSPLANTED FISH

Fecundity or reproductive potential of the transplanted fish is an important consideration. Whilst natural fecundity differs with species, it also varies within the species with age, size and as already mentioned, the availability and types of food.

(vi) PREVALENCE OF ENEMIES

The natural enemies of fish are many. They range from plants like *Utricularia* which trap young fish, to such other predators as insect larvae, predaceous fish, snakes, birds and otters. These are direct enemies. Indirect enemies are those which either compete with the introduced fish for food or destroy their suitable living conditions. The common carp, for example, is an indirect enemy of game fish in temperate regions (Cahn, 1929 and Clements & Shelford, 1947).

(vii) DISEASE

Whilst fish are subject to many diseases, epidemics rarely occur in natural waters. In ponds, however, *Ichthyophthirius* may become an epidemic under conditions of over-crowding or following a period of heavy rains. Learnean copepod parasites have been known to cause trouble in Malayan ponds during dry spells, especially when the pond water is rich, and has an abundance of blue-green algae.

TRANSPLANTATION IN BRACKISH-WATER

The problem of transplantation in brackish-water depends primarily on the ability of the selected species to adapt itself to varying ranges of salinity. Once a suitable choice of fish is made, the other factors follow.

Transplantation in brackish-water is mainly concerned with the rearing of *Chanos chanos*, mullet, species of Penaeid prawns and more recently, *Tilapia mossambica* (Vaas, 1947 and Le Mare, 1950).

The culture of *Chanos chanos* has received much attention and has been described (Sunier, 1922 ; Vaas, 1947; Schuster, 1949a). Success for its cultivation would appear to depend on regulation of soil condition, salinity and depth of water for optimum growth of algae (Arriola, 1941), of which the blue-green is said to be especially desirable.

T = Top Soil.
S = Sub-soil at 3 feet below surface.
† = Personal communication from Agricultural Officer, Krian (1941), Malaya.
‡ = Extract from *Malayan. Agric. Jour.* 1933, page 629.

CONCLUSION

Having discussed in general terms the physical, chemical and biological factors which influence any fish population within its natural ecological environment we may conclude :—

(i) Fish, in general, have a wide range of toleration to the natural physical and chemical factors of the environment. This is not surprising, because the class *Pisces* itself as a whole is one of the most plastic groups among the Vertebrates, with habitats ranging from the abyssmal depths of the ocean to rivulets and torrential streams of the uplands.

(ii) Of all the physical and chemical factors affecting the viability of fish in their natural environment, oxygen concentration is the major limiting factor. Certain tropical fish have anatomical adaptation to air-breathing which gives them a wider range of tolerance to oxygen concentration than fish that solely depend on dissolved oxygen.

(iii) For any fish population which tolerates the available physical, chemical and biological factors in its environment, food availability within the range of natural food selection and suitability for that population becomes the limiting factor.

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